JPRS-CST-93-014
17 August 1993

JPRS Report

Science & Technology

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JPRS-CST-93-014 17 August 1993

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Comprehensive Nuclear Test Ban Objectives, Definitions, and Related Issues

93FE0780 Beijing INSTITUTE OF APPLIED PHYSICS AND COMPUTATION MATHEMATICS in Chinese Jun 93 pp 1-8

[Text of statement by Chen Xueyin [7115 1331 0603] at the Chinese-United States Informal Session on Arms Control, 31 May to 2 Jun 1993]

[Text] Based on the issues set forth by our American friends, this is my first statement. The topic is "The Objectives, Definitions, and Related Issues of a Comprehensive Nuclear Test Ban (CTB)". I am prepared to discuss the following three areas:

1. From the perspective of nuclear disarmament and nuclear arms control, what are the objectives a CTB can attain, what does it neglect and what are its functions, and can it attain the desired objectives?

2. CTB definitions, programs, and related issues or indeterminateness.

3. Should a CTB prohibit all research and development work related to nuclear weapons technology, such as fusion and fission laboratory research?

I. The Role or Objectives of a CTB in Nuclear Disarmament and Nuclear Arms Control

In general, we wish to attain two objectives or foster two roles: 1) A global CTB can prevent non-nuclear nations from developing nuclear weapons, which means preventing the appearance of new nations with nuclear weapons or so-called horizontal nuclear proliferation. 2) Preventing nuclear countries from studying, developing, and deploying new nuclear weapons (in actuality, nuclear warheads) to curb nuclear competition, which is so-called vertical nuclear proliferation.

These two areas are interrelated. Many countries that participate in the NPT are dissatisfied with the major efforts of the United States and Soviet Union in the past at nuclear arms competition and consider a CTB to be the best method for stopping nuclear arms competition and link the achievements of the nuclear nations in implementing a CTB with the continued effectiveness of the NPT in 1995. In reality, both of these are NPT objectives. However, there are now several "de-facto nuclear weapons states", "threshold nuclear weapons states," and "potential nuclear weapons states" that are not participants in the NPT and that have not accepted its restrictions on the development of nuclear weapons.

What we wish to point out is that a CTB is merely one measure for nuclear disarmament and nuclear arms control and that only in a situation of substantial progress in other areas in nuclear disarmament and nuclear arms control can a CTB be truly achieved, which is to say that only then can a true CTB be achieved. The most fundamental objective as well as the most urgent objective in nuclear disarmament is to eliminate or reduce the threat of war or the use of nuclear weapons. Viewed in terms of this point, a CTB is obviously not the most urgent problem, nor is it a vanguard or leading issue. Moreover, a true CTB should help spur comprehensive nuclear disarmament, which is a step toward the ultimate goal of the complete prohibition and total destruction of nuclear weapons. It cannot be a tactic for "attempting to limit other countries while actively preserving and developing one's own advantage". I feel that what CISAC advocates is very sensible, which is that "the United States cannot gain its security at the expense of increased insecurity for other nations" (see The Future of the U.S.-Soviet Nuclear Relationship, NAS 1991). This is to say that we cannot not merely consider ourselves but must also consider others. This is a principle that should be observed when dealing with issues that concern mutual international security interests, and they cannot proceed otherwise.

1. Can a CTB prevent the appearance of new nuclear states and prevent horizontal proliferation? It would seem that a CTB would play a very limited role in this area. Simply relying on a CTB will not attain this objective or will make it very hard to attain this objective.

1) Everyone knows that two basic factors determine whether or not a nation develops nuclear weapons. One is consideration of the political and security interests of that country which create a need, motive, or option for nuclear weapons. The second is its technical and economic capabilities. However, the first factor is the primary or decisive one. Only when they have this need or option will they try every possible way to develop them sometimes without regard to the risk. Generally speaking, the nations that now maintain or are attempting to develop nuclear weapons certainly understand that this is behavior that concerns their major security interests. Simply relying on a CTB will not solve the problem of this type of "need or option". A better measure is to do more work according to different situations that helps to eliminate or alleviate this type of need or option, such as eliminating threats. On the other hand, there is the role of actively reducing or restricting nuclear weapons and eliminating the threat of using nuclear weapons, which may be even more important. This is the responsibility of the nuclear states, among whom the United States and Russia should play a leading role. The present situation is not this way, however. If the United States fails to readjust certain methods (policies), it may cause the opposite, which would run counter to this. The East-West confrontation led by the United States and Soviet Union (Russia) has now basically ended but global regional and local conflicts and contradictions are greater in number and more acute, and wars may even occur. The United States and Russia are still using their powerful military strengths to intervene in world affairs. In particular, the United States is a

global superpower and it feels that all events in all regions of the globe are related to the interests of the United States. As a result, the United States is involved in regional and local conflicts and there is even a high probability of war. In certain regions (such as other independent countries of the CIS, Eastern Europe, South Asia, etc.), Russia may also become involved in conflicts. The problem here is that, based on the progress of the United States and Russia in nuclear disarmament such as the achievement of START-2, after 2003 the United States and Russia will still be deploying excessively powerful strategic nuclear weapons or tactical nuclear weapons (the United States and Russia will deploy 3,500 and 3,000 strategic nuclear weapons, respectively, with a destructive force estimated at 900 to 1,200 MT, and they will also deploy 5,000 to 7,000 nuclear warheads, according to DOD and CDI data). Moreover, because START-1 and START-2 do not restrict non-deployed nuclear warheads (no limit on the total number of non-deployed warheads), they are not required to destroy and dispose of the remaining nuclear warheads, and do not even have to destroy and dispose of the missiles they eliminate. In reality, this is equivalent to "eliminating deployments, expanding reserves, and maintaining strengths". Moreover, there can be more nuclear weapons held in reserve than are deployed, or at least a huge number of them. The United States is now proposing a shift in its strategic focus to the prevention of nuclear proliferation. The problem is that the United States and Russia are maintaining such huge nuclear war capabilities, and the United States has not agreed to the Russian proposal for a completion elimination of nuclear alerts (zero-alert) and it maintains a policy of the allowing the first use of nuclear weapons. In this type of situation, how can other countries, especially those on guard against the United States and Russia or those countries in direct or indirect conflict with or even opposed to the interests of the United States and Russia, abandon the nuclear option? Some in the United States have advocated the use of coercive measures to coerce those countries, but this is not the best policy and would not be certain to be effective, and it could even be dangerous. There is an idiomatic phrase used in China to criticize inequality between the strong and the weak which says "the magistrates are free to burn down houses, while the common people are forbidden even to light lamps". Fundamentally and in the long term, in international affairs, especially those that affect the security interests of a country or a nationality, this method is not possible. 2) Developing elementary or crude fission weapons and even producing a small quantity of them and establishing a very small nuclear weapons stockpile does not necessarily require nuclear explosion tests. This is a fact. The United States did not conduct a nuclear test prior to dropping the first gun-type atomic bomb on Hiroshima on 6 August 1945. Israel and South Africa have developed and established a very small elementary nuclear weapons stockpile yet they have not conducted nuclear tests (although there is suspicion that one was conducted in September 1979, but there is not sufficient confirmation of this). The facts have shown that the present national technical measures (NTM) are not adequate to discover this type of situation. As for on-site inspections (OSI) like the U.N. group's inspections in Iraq, it would be hard to determine the situation without the internal coordination and assistance of Iraq.

In the area of nuclear technology, there are many similarities in technology, personnel, facilities, and other areas between those for military and civilian purposes. For quite some time the basic principles or concepts for designing elementary nuclear weapons can be read in books and journals. There are also many companies in the West who have used a variety of legal and illegal routes to sell the relevant technologies and equipment in order to earn huge profits, and there is much dual-use technology and equipment that is hard to control completely. The ability of Israel, South Africa, Iraq, and other countries to develop nuclear weapons is an example, and a CTB will not solve such problems. However, the development of more advanced nuclear warheads, especially thermonuclear weapons, is impossible without a substantial number of nuclear tests. A CTB would play an extremely limited role in this area. As for preventing horizontal proliferation, strict controls on the development, production, and transfer of fissionable materials for military purposes, especially strict controls on chemical processing and concentration technology and equipment, should be said to be the key and even more effective.

2. In the area of preventing vertical nuclear proliferation, meaning the area of progress in spurring nuclear nations to nuclear disarmament and arms control, the role and significance of a CTB would also be very limited. Of course, a true CTB (depending on the definition) could prevent research, development, and deployment of new nuclear warheads and help prevent fierce nuclear competition like that between the United States and Soviet Union in the past. However, the present situation has changed: 1) The nuclear competition between the United States and Russia has already lost its foundation and motive power. England, France, and China are merely starting with their national defense and are only maintaining the lowest nuclear deterrent capability and are not involved in nuclear competition. As for nuclear technology, the United States and the Soviet Union (Russia) had already approached the flat top of the "S" curve in development long ago (this is the earliest assessment by York). After the 1970's, for instance, there were very few changes in the specific yield (yield-to-weight) of nuclear warheads and they mainly used improvements in their delivery vehicle launch systems (SNDV) and C^3I to improve and increase their nuclear war making capabilities. As for nuclear weapons development, the United States and Soviet Union (Russia) could have stopped their nuclear tests quite some time ago.

Besides conducting a small number of nuclear tests to improve the safety and examine the reliability of the strategic and tactical nuclear weapons (the so-called second generation nuclear weapons) that the United States and Russia now have deployed (there could also be effects tests, tests to improve new delivery vehicles related to improvements in warheads, etc.), they do not need to conduct more R&D tests. Of course a CTB or stricter limitations on nuclear tests could prevent the United States and Russia from doing R&D on the so-called third generation nuclear weapons, limit optimum configurations of new delivery vehicles, and so on. The situation is changing, however, and many people in the United States feel they are unnecessary and plan to reduce them substantially and have partially stopped them. 2) Russia has been incapable and unwilling to continue its nuclear competition with the United States for some time now and has proposed an even larger and more thorough nuclear disarmament, such as reducing the number of strategic nuclear warheads deployed to 2,000 to 2,500, completely eliminating nuclear alerts (zero-alert), exchanging and announcing key data on nuclear weapons (such as the total number and types of nuclear warheads, total stockpiles of fissionable material for military purposes, etc.). The latter is the foundation for evaluating true large-amplitude nuclear disarmament and the development of nuclear inspection technology (if the total number is unknown, how can the magnitude be evaluated?). The United States has not responded to any of these. Instead, it would seem that the United States is using the temporarily weaker status of Russia to develop its own advantages, for example, the serious inequality in START-2, which has already aroused dissatisfaction among many people in Russian military circles and there may be resistance to approval in parliament. One can imagine that if it is possible Russia will try to strengthen and improve its SLBM and ASW capabilities. History has proven that advantages are always temporary, and the nuclear competition between the United States and Russia may not have ended. 3) The United States and Russia both have absolute superiority in the two areas of nuclear weapons technology and nuclear weapons capabilities, and they have done a great deal of research in the areas of post-test ban technical preparations and nuclear inspection technology, so it can be said that they have made substantial preparations. Moreover, if START-2 is achieved on schedule, the number of nuclear weapons deployed by the United States and Russia will still exceed the nuclear forces of England, France, and China by several numerical grades, so many scholars in the United States feel that now is not the time to ask England, France, and China to join in nuclear disarmament negotiations. The British and French governments also have stated clearly that they would not participate in nuclear disarmament talks prior to changes in the quantitative differences in nuclear forces. Several scholars have proposed that the United States and Russia should immediately begin START-3 negotiations and reduce their deployments of strategic nuclear warheads to 2,000 to 1,000 (Dr. Garwin present here also has made a similar proposal), and they could even reduce them to a few 100. We advocate truly comprehensive nuclear disarmament in that we should reduce those deployed and reduce and control those in reserve (non-deployed), and all of the reduced nuclear warheads and carrying tools should be destroyed and disposed of. They should at the least be controlled and not re-used as nuclear weapons.

A true CTB cannot simply be a freezing of the current situation. Doing so would on the one hand not push nuclear disarmament forward and on the other hand, I fear that the different development phases and differences in actual conditions in each country would make a simultaneous cutoff impossible. After the United States Congress passed a bill concerning a test ban, England and France both indicated that because of the demands of the situations in their own countries, they could not stop nuclear testing, which is understandable.

In essence, our view is that if we wish to achieve a true CTB, especially if we want to attain the objectives envisioned for a CTB (achieving a CTB would not make it certain that the desired objectives for a CTB would be attained) and continue and strengthen the NPT, which means a global nuclear non-proliferation system, we must adopt more effective fundamental measures in the areas of nuclear disarmament and arms control. First, for example, we could prohibit the use of nuclear weapons like the global treaty to prohibit the use of biological and chemical weapons. If this is possible, then the desired objectives of other issues such as large magnitude nuclear disarmament and a CTB and NPT could all be readily solved and everyone on the globe could avoid nuclear catastrophes. If the subsequent part is not achieved, the intermediate phase or transitional phase should limit the use or role of nuclear weapons, such as only using nuclear weapons to avenge a nuclear attack, which would allow other weapons of mass destruction (such as biological and chemical weapons) to play a deterrent role (threatened use). This is the policy of "no first use." The nuclear nations should bear the responsibility of not using nuclear weapons against non-nuclear regions. One important measure that could be used for nuclear inspections is a complete elimination of nuclear alerts. "Prohibiting use" or "no first use" eliminates the possible threat of nuclear weapons attacks and are the most conducive to the elimination or alleviation of the need and enthusiasm for nuclear weapons, and would be the most conducive to promoting the achievement of the objectives of a CTB and NPT, so it could be viewed as the most fundamental measure based on trust in the nuclear arena. The United States has made prevention of nuclear proliferation its focus, and it should make new efforts in this area, while all of the nuclear nations should make their own efforts.

II. The Definitions and Issues of CTB and Indeterminateness

First of all, there must be a clear definition of a CTB because otherwise everyone will do as they please and the name will not correspond to reality, and it will be impossible to formulate nuclear inspection standards. If a low-yield threshold is established, it would mean substantially different degrees of limitations at different technological development phases.

We hope that a CTB will truly help promote comprehensive and total nuclear disarmament, which means taking a step toward the ultimate goal of a complete prohibition and total destruction of nuclear weapons. This definition should be "prohibiting all nuclear explosion tests". "All" includes R&D related to nuclear weapons and conversion to weapons (safety and effectiveness tests) as well as the maintenance of effective and reliable inspection and all other nuclear tests, which means prohibiting any type of nuclear explosion testing. This would create a situation in which no R&D could be done and would restrict maintenance and improvement. As time passed, the reliability (trustworthiness) of existing nuclear warheads would gradually decline and they would lose effectiveness. This provisionally would not include laboratory fusion and fission research (to be discussed below). Based on this definition, the nuclear explosion yield would be $Y_{CTB} \approx 0$. This definition is determined on the basis of the objectives that we wish to attain with a CTB. The nuclear tests prohibited in this case would include one-point safe tests, which in the United States is $Y_{OPS} < 2$ kg TNT), that are the so-called hydronuclear tests. The high energy density facility (HEDF) envisioned in the LLNL is ($Y_{HEDF} <$ 0.3 KT). Although the laboratory miniature fusion facilities envisioned in the United States' ICF plan have a projected successful nuclear fusion energy output of as much as 100 to 1,000 MJ, equivalent to 20 to 200 kg of TNT, because the system has dual uses and is qualitatively different, other discussions will be held. This type of definition requires nuclear inspections to a 0 yield. In actuality, it prohibits the testing of any type of nuclear explosion device regardless of the size of the yield. This type of truly thorough CTB is very hard to inspect (theoretically, they could be conducted in a concealed manner at any time and any location on the globe, and there is also interference from chemical explosions and earthquakes). United States Department of Defense Secretary H. Brown (1977-1981) stated that this type of CTB cannot be achieved ("a CTB is not in the cards"), and Dr. R. E. Kidder who is present here has discussed this issue. I feel that nuclear inspections require the development of a new concept and are not necessarily limited to seismic detection, for example things like nuclear inspection research and testing facilities, and all this requires further R&D.

Some people have proposed substituting the Low Yield Threshold Test (LYTT) for CTB, and this type of program also touches upon many issues: 1) There is much disagreement about how to set Y, the so-called minimum test yield Y_{ms} (Y_{ms} = the lowest yield of military significance). The proposals made in the United States in the past include:

John S. Foster $Y_{ms} < 0.25$ KT (1973); Harold M. Agnew $Y_{ms} < 5$ KT - 10 KT (1973); Harold Brown $Y_{ms} = 0$ (1977-1981)

In reality, Y_{ms} varies substantially with different testing objectives, different technological development stages, and different (accumulated) experience. People are aware that computers can be used for simulations so that low-yield tests are calibrated and magnified to large yields. This cannot be done in countries that are beginning to develop nuclear weapons, and they can only conduct full-yield tests. The 1 KT threshold now being recommended by the United States basically conforms to the development levels and needs of the United States (and Russia). The United States and Russia conducted a large number of low-yield ($Y < 1$ KT) nuclear test studies in the past. One of the main aspects of the Test Ban Readiness Plan implemented in the United States since 1988 has been using under 1 KT nuclear test studies to estimate the capability of an elementary full yield (such as about 5 to 20 KT). Obviously this definition means "restricting other countries, developing one's own advantages". Foster proposed that 1 KT and even ½ KT or ¼ KT all have military significance (here the discussion has been omitted). 2) The issue of detection limits and estimating limits.

Y_d—the lowest limit explosion yield reliably detected and identified—may be several KT or 1 to 5 KT at the present time. This was estimated based on analysis of some of the tests at sites in the United States and Soviet Union (Russia) and it is hard to extrapolate this to other regions of the world. If it is 1 to 5 KT, this would require a substantial number of external seismic networks and the establishment of a substantial number of network stations within the country. This type of detection involves a considerable degree of intrusiveness and concerns political and foreign relations issues. There is also the issue of the estimable Y_E, which is the lowest yield (tested) that can be estimated with proper accuracy. The error in the estimable yield limit is too large, so the inspections would be insignificant. The 150 KT threshold stipulated in the TTBT requires the use of CORRTEX to attain an error of plus or minus 30 percent. Moreover, low yields may also require consideration of evasive technology, and differences in the geological structures at the test site are even more acute. The dry alluvial deposits of the loose geological structure at the United States's Nevada test site may reduce the seismic signal several times to several 10 times. Some people in the United States have pointed out that it is very hard to discover tests under 1 KT in this type of geological structure. 3) The most important thing is the 1 KT threshold. LYTT is certainly not a CTB and it runs counter to the objectives of a CTB. If we only take into consideration

the technological development advances and needs of the United States and Russia in considering the definitions, there is of course no reason to request that other countries participate.

If an intermediate program is required, it would be best to have a quota program to restrict the number of tests. Strictly controlling the number of tests could block R&D on new nuclear warheads and achieve the objective of preventing nuclear competition, which could partially satisfy the desires of the non-nuclear states and avoid several of the disputes concerning the LYTT described above. Of course, a quota is not a CTB and efforts must still be made in the direction of a CTB.

In essence, there are two views: 1) The conditions necessary for achieving a true CTB are lacking at the present time, and there are many problems to solve in both the political and technological areas. 2) As for achieving a true CTB, it will be hard to attain the objectives by simply relying on a CTB. More effective fundamental measures must be adopted in other areas.

III. Should or Can a CTB Prevent All R&D Work Related to Nuclear Weapons Technology?

If we wish to attain the objectives of a CTB, we must prevent all work that could aid in R&D on and improvement of nuclear weapons technology, which could include laboratory research, such as ICF plans for military purposes. In the broad sense, some people in arms control circles proposed including military R&D in arms control quite some time ago. Several years ago we also proposed that scientific circles should prevent R&D on new weapons of mass destruction that threaten the global ecology and the environment in which mankind exists. Most people in scientific circles hold this desire. How it can be achieved and whether it can be achieved, however, is a scientific and technological issue as well as an even greater political issue. As far as nuclear weapons technology is concerned, it will be very hard to achieve.

1. Fusion and fission research has dual uses. For example, inertial confinement fusion (ICF) has many similarities to thermonuclear weapons and laboratory miniature fusion is equivalent to the explosion of a miniature hydrogen bomb. It certainly can be used to study even more weapons physics questions, but it is also a very hopeful route for achieving the peaceful use of fusion energy. I am afraid that refraining from doing something necessary for fear of a risk is not a good idea. We should have a cautious attitude concerning dual-use technologies. Actually, the situation is similar for biochemical weapons and other high-tech weapons, which depend on the development of many types of technologies. This is a very complex issue that should not be dealt with simply.

2. There is a substantial distance between the R&D stage and conversion into a weapon. For nuclear weapons, applying laboratory research results (such as ICF) in weapons designs usually still requires conducting nuclear tests, especially of new principles and new concepts. This returns us to the nuclear testing issue. ICF cannot totally replace nuclear explosion tests.

3. The R&D stage is very hard to inspect, with the exception of mutual participation in experimental research and design. This type of highly intrusive inspection system would appear to be hard to accept at present. No type of S&T research is independent, which also concerns S&T classification issues, especially for military S&T.

4. As for the objectives of a CTB, other routes may be even more effective. such as a fundamental solution to the problems to prevent the use or restrict the use of nuclear weapons.

The desire to prohibit all related R&D work is understandable but very hard to achieve in reality.

Status of Science and Technology R&D

93FE0712A Guangzhou KEJI GUANLI YANJIU [STUDIES IN S&T MANAGEMENT] in Chinese No 2, Mar-Apr 93 pp 6-10

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[Text] Research and development (abbreviated as R&D and including basic research, applied research and experimental development) are important components of science and technology activity and are the center of the entire S&T endeavor. Investment in R&D has an important impact on the growth of the economy and the advance of the society. The S&T strength of a nation is reflected on the personnel, money, and material invested in R&D. For this reason, this article will emphasize the analysis of China's R&D investment, the distribution of R&D departments, and the role of China's R&D in the world.

I. Personnel Resource Investment in China's R&D

Human resource is the power for economic, technological and societal development; it is therefore given an important position in every country in the world. In personnel resources, R&D personnel is the core.

Like R&D budget, the number of R&D personnel is an important indicator for understanding the direction and potential of research and development. Research and development personnel is the main body of R&D activity; the quantity and quality of R&D personnel are major indicators for the science and technology strength of a country, and are also important constraints in S&T advancement and social economic development. Research and development personnel refers to all the personnel primarily devoted to R&D and support personnel directly serving R&D. R&D

personnel may be divided into three categories: scientists and engineers, technicians, and support staff. Scientists and engineers are the basis and center of R&D personnel. In the statistics of R&D personnel, the personnel are divided according to their activity into full-time workers, part-time workers, and full-time equivalents.

1. Total Number of R&D Personnel in China

The total number of R&D personnel reflects the scale of the R&D activity and, in a sense, the S&T strength of a country. It is an important marker for S&T personnel investment of a country. According to China's survey and projection of its R&D activity, the total number of R&D personnel in 1988, 1989, and 1990 are respectively 477,000, 492,000, and 512,000; out of which the number of scientists and engineers for these years are respectively 295,000, 310,000, and 333,000, which are respectively 61.8, 63, and 65 percent of the total numbers. This shows that scientists and engineers are the main body of China's R&D personnel. Among the R&D and S&T personnel, the numbers of scientists and engineers, technicians, and support staff are approximately in the ratio of 3:1:1.

Both the number of R&D personnel and the number of scientists and engineers in R&D personnel have increased in China in recent years. Their rate of increase in the 1987-1990 period were respectively 5.8 and 8.8 percent. The R&D personnel, as a percentage of the total S&T personnel, were respectively 4.94, 4.75, and 4.47 percent in 1988, 1989, and 1990. These figures showed that there have not been large changes in recent years and the percentage has been roughly 4.8 percent. This value appears to be somewhat low now. The total number of R&D personnel in China in 1990 was 512,000, which was not a small number. However, in terms of the large population of China and the wide scope of S&T activities, the number was really not large on a relative basis.

2. Departmental Distribution of China's R&D Personnel

The three large S&T departments in China are the government R&D organizations, universities, and industrial enterprises of large and medium scale. More than 90 percent of China's S&T activities are concentrated in these three departments. It is helpful to analyze the R&D personnel distribution in the three large sectors in our attempt to understand the structure and deployment of China's R&D personnel.

More than half of China's R&D personnel are concentrated in R&D organizations. The percentages of R&D personnel in R&D organizations relative to the total R&D personnel in China were respectively 52.7, 52.8, and 50 percent for 1987, 1988, and 1989. Industries and universities each have 25 percent of the R&D personnel. Judging from the distribution of R&D personnel in the implementation departments, R&D organizations assumed the main responsibility for China's S&T and R&D activities. Sixty-five percent of China's scientists and engineers in R&D personnel are concentrated in the R&D organizations. Of the industrial R&D personnel, 31 percent are scientists and engineers and 69 percent are technicians and support staff. Judging from this profile, the research and development in China's enterprises are mainly experimental developments and there should be more technicians and support staff. Among the R&D personnel in the universities, scientists and engineers make up an extremely high percentage; in 1989 it was 91 percent. This shows that China's universities have a strong R&D force of high quality, it also shows the need to reconsider the ratio of scientists/engineers, technicians, and support staff. In universities the main activities are basic and applied research, so the percentage of scientists/engineers should be higher than that in R&D organizations and in industries. Today, there is only one technician or support staff for every nine scientists and engineers in universities, which is obviously too low.

II. Financial Resources in China's R&D

Monetary investment is one of the indispensable conditions in R&D and also an important component in S&T policy and management of a country. The magnitude and structure of R&D funding to a certain degree reflect the ability of a country to invest materials and information resources and to build organizations. It not only represents the scale and quality of a nation's S&T development, but also the attention given to S&T development by a country.

1. Total R&D Funding in China

Research and development funding is an important supporting condition for a country's S&T activity and economic development. According to R&D funding data of the State Science Committee, China's R&D budget has increased every year from 1987 to 1990. The figures were 7.403 billion yuan for 1987 and 12.18 billion yuan for 1990, the increase was 64.5 percent. From 1987 to 1990, the annual rate of growth in China's R&D funding was 18 percent—not a small growth. In terms of constant dollar, however, the annual rate of growth was only 5.18 percent, which was lower than the 6.8 percent annual rate of growth in China's GNP for the same period. In 1990, China's total S&T budget was 30.05 billion yuan, and 40.5 percent of that was for R&D; this percentage was somewhat too low.

China's R&D budget as a percentage of its GNP has been fluctuating between 0.6 and 0.7 percent in recent years. It was 0.65 from 1987 to 1988 and 0.7 percent in 1990. China's R&D/GNP ratio is only about average in the world's S&T development history and economic development stages and is far from adequate to satisfy the needs in S&T development and economic construction.

2. Sources of China's R&D Funding

There are two main sources for the R&D budget: government allocation and non-governmental support, with the latter coming from a variety of channels in the society. Today, most of the non-governmental support comes from industry and the other raised by the research organizations and universities themselves.

Half of China's R&D budget relies on the government, but non-governmental support has also increased in recent years, from 3.024 billion yuan in 1988 to 5.295 billion yuan in 1990. This shows that multichanneled sources for China's R&D funding are in the formation process. Because of China's inadequate commodity economy, R&D funding will still be coming from the government in the near future. The percentages of R&D funding coming from government allocation is the highest in government R&D organizations (77.9 percent), followed by universities (68.4 percent), and industry (49.4 percent). The majority of China's research institutes devoted to basic and applied research are concentrated in government research organizations and universities. It is therefore reasonable that government allocations exceeded one-third [as published] of their R&D budget.

3. Types of R&D Funding in China

Research and development activities may be divided into basic research, applied research, and experimental development. One of the main issues in formulating S&T policy and management of S&T is an evaluation of the distribution of R&D funding in these three areas. The fraction of R&D funding for basic research is of particular interest to policy makers.

In recent years, China spent between 600 and 800 million yuan on basic research, which amounts to about 7 to 8 percent of the total R&D expenditure. It is clear that China's funding for basic research is too low, especially if one considers the fundamental, guiding and originating role of basic research for the fast developing high technology. It is imperative that China's basic research capability be strengthened without delay so that the staying power in S&T development can be improved. An analysis of China's S&T development and national economic development requirements shows that expenditure on basic research should be raised to at least 10 percent of the total R&D funding. Only then can China become competitive in the arena of high technology and basic research.

III. China's Role in the World's Research and Development

It is a very complex task to compare the R&D activities in the world because of two reasons. First, there has not been a complete scientific system to gauge the S&T activities in different systems of different countries. Second, R&D activities are affected not only by internal factors but are also constrained by national politics, and social and cultural background. The comparison of international R&D activities given below can therefore only be considered a preliminary quantitative measure using statistical indicators.

1. Personnel Resources in R&D

In 1989 there were 492,000 R&D personnel in China, which was more than the number in developing countries, comparable to the 1987 level in Germany and less than that in Japan, the United States, and the former Soviet Union.

In terms of the total number of R&D personnel, China follows behind Japan, the United States, and the former Soviet Union and ranks fourth in the world. In terms of the per capita figure, however, China ranked very low. The number of scientists and engineers in R&D personnel is an important indicator. In 1989 China had 310,000 scientists and engineers, less than that in Japan and the United States, but far exceeded that in India, Brazil, and South Korea. In 1989 there were 442 scientists and engineers per million population in China, which was lower than the United States (3,265), Japan (4,853), and South Korea (1,129), but slightly higher than India (220) and Brazil (400).

The distribution of R&D personnel in different departments is not only an indication of the trend of personnel flow in a country but also a profile for the S&T policy and system. In developed countries more than half of the R&D activities are done in the industries and enterprises. In developing countries, on the other hand, most of the R&D activities are done in government research organizations. In 1989, almost one-half of China's R&D personnel were concentrated in government R&D organizations; universities and industries basically had one-fourth each. This is basically consistent with the characteristics of a developing country R&D activity.

2. Financial Resources

Investment in R&D is an issue that attracts great attention of governments; it is also an important indicator for evaluating the S&T development of a country. Today there are two indicators for the size of R&D investments: one is the absolute number of R&D expenditures and the other is the R&D expenditure as a fraction of the GNP (R&D/GNP). Since different countries are at different stages of economic development, it is more meaningful to compare the latter.

Today the R&D expenditures of developing countries generally fall below 1 percent of their GNP whereas in developed countries the number is generally greater than 2 percent. In 1980 the average value was 0.45 percent for developing countries and 2.25 percent for developed countries.

From 1987 through 1990, China's R&D/GNP value was respectively 0.65, 0.64, 0.65, and 0.7 percent, far less than the level in developed countries (and also less

than that in South Korea and India), but slightly higher than that in developing countries. A review of the R&D investment in various countries at different stages of economic development shows that China's current R&D/GNP is equivalent to that of Japan in the 1950's (0.63 percent) or that of South Korea in the 1970's, but slightly higher than that of Brazil for the same period.

China's current R&D/GNP value is too low. It is not only far below that of developed nations, but also considerably behind developing nations like India. The situation in China is that inadequate S&T investment hampered the development of R&D. If the situation continued, it would affect the prosperity of China's economy and the staying power of China's sustained development.

In today's world, the annual rate of growth of R&D expenditures in almost all developed nations is greater than the rate of growth of their national economy. In some newly industrialized nations like South Korea, the growth in their R&D expense during the development period was still far greater than their growth in national economy. From 1987 to 1990 in China, although the R&D expense grew at a rate of 5.18 percent per annum (based on constant dollar), the national economy grew at a rate of 6.7 percent per annum. This situation obviously cannot satisfy the need in S&T development.

Funding sources for R&D are an important area in a country's S&T development structure and the relationship between S&T, the society, and the economy. R&D fundings come mainly from two sources: government allocation and fund raising from various channels (mainly enterprise investment). On the whole, enterprise investments on R&D in developing countries are generally less than 20 percent of the total R&D expenses. In developed countries, enterprise investments in R&D are generally higher than 50 percent of the total R&D dollars. Part of the reason is the system. In developed countries most of the R&D organizations and laboratories are distributed in enterprises; they are not only the main supporters of R&D but also the implementers of R&D. In developing countries, most of the R&D activities are conducted in government R&D organizations and the government is the main investor for R&D. It can be said that R&D activities in developed nations are "enterprise driven" whereas R&D activities in developing nations are "research type."

In China today the enterprises invest less than 20 percent of the R&D expenses, which is quite low. Although the Chinese government is supporting most of the R&D, China is faced with an urgent task of improving the S&T of enterprises and increasing the investment in R&D.

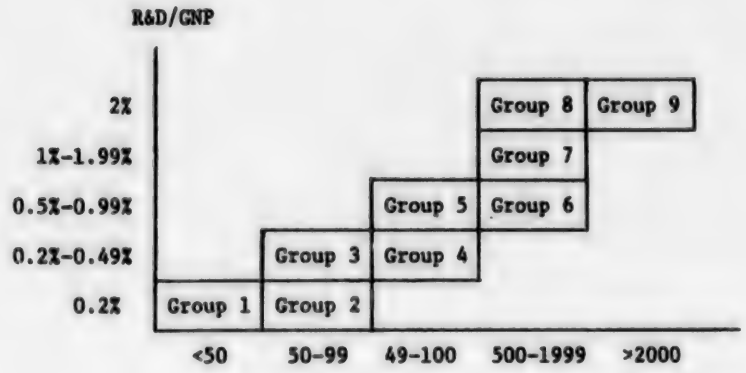
An important indicator for a country's S&T development is the ratio of basic research, applied research and experimental development in R&D funding. However, the distribution of funding for basic research, applied research, and experimental development is a very complicated issue and there is no fixed model in the world. Due to differences in systems in various countries, the funding distribution also differs. Even in the same country, the distribution changes in different stages of economic development.

Today, the distributions of R&D funding in developed nations are generally 13 to 15 percent for basic research, 20 to 25 percent for applied research, and 60 to 65 percent for experimental development. In some newly developed industrial nations such as South Korea, the percentage for basic research can be as high as 24 percent. Even in large developing countries like India, the investment in basic research is 13 percent of the total R&D funding. In China, the investment on basic research is only 7.2 percent, which in comparison is obviously too low. Judging from the S&T development experience of other countries, China should raise its investment on basic research to 10 percent.

3. Comparison of the Compound Index

In order to further analyze the role of Chinese R&D in world development of S&T and to examine the world S&T development trend more directly and comprehensively, we compare the development of S&T in different countries using two compound indices: the ratio of R&D expenditure to gross national product (R&D/GNP) and the number of R&D scientists and engineers per million of population. We construct the following two-dimensional diagram using the number of R&D scientists and engineers per million people as the abscissa and the R&D/GNP ratio as the ordinate.

Countries in the first three groups are still in the early stage of S&T development, their S&T bases are still weak and they lack both money and people for S&T. Countries in Groups 5 and 6 have some S&T base and personnel and financial resources for S&T. Their R&D expenditures are in the 0.5 to 1 percent range of their GNP. Some countries in these two groups may have a rather high percentage of R&D personnel in their population. Most of the countries in the last three groups are already developed nations with a strong S&T base. Since these countries have relatively good economic base and strong competitive power, they invest substantially in S&T personnel and funding. China belongs to Group 5 and is in the middle of the ranking based on the two compound indices.



R&D Personnel Including Scientists and Engineers per 1 Million people

Using the above diagram to analyze representative countries quantitatively, we obtained nine groups:Group 1: Philippines, Afghanistan, Nepal;Group 2: Central African Republic, Cyprus;Group 3: Burundi, Pakistan, Fiji;Group 4: Portugal, Egypt, Indonesia, Thailand, Brazil, Nicaragua, Greece, Sri Lanka;Group 5: India, China, Chile, Spain;Group 6: Ireland, Yugoslavia, Cuba, Singapore;Group 7: Canada, South Korea, Finland, Australia, Denmark, Italy;Group 8: France, United Kingdom;Group 9: United States, Japan, Sweden, Germany.

SSTC Gives Priority to Electric Vehicle, HDTV Among 10 Key Projects

93P60308A Beijing KEJI RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese 30 Jun 93 p 1

[Article by Yu Xiaohan [0060 1420 2498]: "Electric Vehicle, High-Definition Television Projects Begun"]

[Summary] Beijing, 28 Jun—Among the State's 10 Major Key S&T Projects selected by the State Science and Technology Commission at the beginning of the year, two projects—development of an electric vehicle and HDTV development—were given priority and the formal go-ahead by late June; moreover, a third project—the year 2000 municipal/rural comfortable dwelling demonstration project—will be begun sometime in the next few months. With regard to electric vehicle and HDTV development, China has been conducting basic research for several years now, and some gains have been realized. The electric vehicle project was initially conceived in Guangdong, and will rely on local forces to compete in the race now going on among advanced nations to industrialize electric vehicles.

Nanjing Science and Technology University Enters Market Competition

93P60312A Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 14 May 93 p 1

[Article by Miu Liyan [4924 4409 1693]]

[Summary] To compete in the world market and to speed up commercialization, industrialization and globalization of its high-tech products, the Nanjing Science and Technology University (NSTU) has targeted a series of its high-tech products for competing. To date, NSTU has established about 30 plants and companies in Jiangsu, Shanghai, Zhejiang, Fujian, Shenzhen and Hainan by its own funds or through joint ventures, to produce items worth 30 million yuan yearly. Recently the university also built two high-tech development zones, one on its campus and the other one in Nanjing Pukou, with a total area of 100 mu. During the past 2 years, the university earned $1.22 million foreign currencies from sales of its 12 products in areas including chemical engineering machinery, electronics and optics to Italy, Australia, the United States, and Kenya. Also in 1992, the university signed contracts with 28 provinces and cities to sell its 150 products valued at more than 26 million yuan, and in early 1993, NSTU even went further and signed contracts with many foreign companies to exports its high-tech products worth $10 million.

China To Establish Productivity Promotion Centers

93P60312B Hangzhou ZHEJIANG RIBAO in Chinese 7 Jun 93 p 5

[Abstract taken from the "Organizational Personnel News"]

[Summary] The State Science and Technology Commission announced recently that in order to promote S&T advancement of the medium- and small-sized, and township enterprises, China is planning to establish productivity promotion centers across the nation. The centers will assist those enterprises that do not have strong S&T strength to adapt themselves to the socialist market economy, by establishing a sound S&T service and supporting system. The enterprises supported by the centers are expected to increase their profits by 5 to 10 percent in 3 to 5 years. The centers will also serve as coordinators between research institutes and enterprises to bring mutual benefit to both sides, so that S&T results can be introduced into the enterprises and a greater market can be opened up to the scientists.

Breakthrough in Super-Hard Materials Processing

93FE0814B Xian SHAANXI RIBAO in Chinese 27 Apr 93 p 1

[Article by Jiang Zengke [5592 1073 4430] and Yang Hua [2799 5478]: "Successful Building of Large Tonnage Press for Artificial Diamonds"]

[Text] China's largest six-sided hinge-type 7,200-ton hydraulic press for super-hard material processing was successfully built in Xianyang and was approved by the provincial authority. Experts affirm that the press has advanced design, and closes a gap in China's backward artificial diamond industry. It is a major breakthrough for super-hard material equipment.

Artificial diamonds, whose research is a key project in the state's development of new materials, have been used as tool materials and functional materials in precision fabrications, electronics, optics, the military, and spaceflight, as well as the chemical and mining industries. For a long time, the equipment used in China's diamond industry limited the production of coarse-grain, high-strength diamonds, and equipment tonnage restricted the enlargement of synthetic body size. To deal with this situation, beginning July 1991, the Xianyang Science Commission assigned the Xianyang Super-Hard Material Research Institute (XSMRI) its key research mission of developing a new product for super-hard material processing. With support of the trial manufacturing plant of the 202 Research Institute, Xianyang Pneumatic Press Factory, and the Xianyang Municipal Construction Bureau, XSMRI built China's large-tonnage press for artificial diamond production after research and trials for 2 years.

Nuclear Technology Research Spawns Super-Sensitive Spectrometer

93FE0814E Chengdu SICHUAN RIBAO in Chinese 14 Jun 93 p 1

[Article by correspondent Zhu Shunlin [6175 7311 2651] and reporter Zhang Xuequan [1728 1331 0356]: "China's Nuclear Technology Research Once Again Achieves Unique Results; World's First Super-Sensitive Cyclotron Mass Spectrometer Successfully Developed"]

[Text] XINHUA, Shanghai, 13 Jun—The world's first super-sensitive small-scale cyclotron spectrometer has been approved today by the Expert Group of the State Natural Science Foundation Committee. This shows that China has again accomplished a uniquely important achievement in nuclear technology research.

The accelerator mass spectrometer (AMS) is a new technology in ion beam analysis, and opens a new realm in accelerator application. It is an important research tool in a series of chronology related sciences such as astronomy, geography and archaeology. It is also widely used in urban and harbor construction, underground water resources and saltwater lake research, as well as data collection for seismology, foundations, oil fields, etc. Currently, the majority of AMS in the world are high energy mass spectrometers utilizing large-scale tandem accelerators. Their construction and operating costs are very high. The Shanghai Institute of Nuclear Research adopted an entirely different design to build super-sensitive small-scale cyclotron mass spectrometer having advantages of both the cyclotron mass spectrometer and the tandem accelerator mass spectrometer. In addition, it costs less to build and requires no radioactive protection shield so that it can be installed at any laboratory location.

The expert opinion is that the successful installation of AMS places China in a leading position internationally in this research field.

First Indigenous Mass Spectrometer Now Operational

93FE0814C Shanghai JIEFANG RIBAO in Chinese 28 Apr 93 p 3

[Article by reporter Tang Qinmei [0781 4440 2734]: "First Accelerator Mass Spectrometer Now Operational. Achievement Meets Advanced International Standard"]

[Excerpts] The first tandem accelerator mass spectrometer (AMS) to be originally designed and manufactured in China is now in operation. The spectra of C-14, Be-10, and Al-26 isotopes have been successfully obtained. [passage omitted]

The AMS, which was made by the Shanghai Institute of Nuclear Research of the Chinese Academy of Sciences, is highly sensitive. It can "capture" a single C-14 atom out of one-quadrillion carbon atoms. It requires a sample weight of only 1 milligram, therefore, the age and the authenticity of an artifact can be determined without damaging the artifact itself. Utilizing the AMS technology, the Institute of Nuclear Research, working with related research organizations, embarked on the following projects: "Be-10 isotope in the lakes of Qinghai Plateau," "the effect of aluminum metabolism on Alzheimer's disease," etc. Experts believe that the Chinese AMS meets international standards, which brings China's ultramicroanalysis technology to a new level.

Aero-Engine Blade Technology Said at World Level

93FE0814D Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 21 May 93 p 2

[Article by Xiong Hesheng [3574 0735 3932]: "China's Aero-Engine Blade Production Reaches World Level"]

[Text] According to the National Defense Industry Office in Guizhou, the Guizhou New-Technology Machine Factory (GNMF) of the Aeronautical and Aerospace Ministry has focused on the application of

high and new-tech. When GNMF learned that Shenyang Metal Institute (SMI) of the Chinese Academy of Sciences had successfully developed laser casting-welding technology, they immediately approached SMI to apply the new technology to the production of aero-engine blades.

The aero-engine blade is a crucial part in aircraft power systems. Traditional forging processes produce blades of inconsistent quality. To ensure the increase of aircraft power, production technology to improve the blade quality should be appropriately modified. As a new technological specialty factory producing aero-engine blades, GNMF, in order to meet head-on the international advanced level, searched and researched nationwide for high quality blade manufacturing technology. In 1992, after the certification of the SMI laser casting technology, GNMF, which is good at "borrowing other people's wisdom to assist its own take-off," immediately "adopted other people's strength for its own use." After cooperative effort of both organizations for a year, a world class turbine blade was manufactured with the modern laser casting technology.

Modern Air Force Research Facility Described

93FE0814A Beijing RENMIN RIBAO in Chinese 10 Jun 93 p 3

[Article by Xinhua News Agency reporter Sun Maoqing [1327 5399 1987] and RENMIN RIBAO reporter Yin Pinduan [1438 0756 4551]: "Air Force Test Base Advances to World Rank"]

[Text] Motivated by the revolutionary spirit of self-reliance, hard work for prosperity, and arduous struggle to achieve pioneer tasks, the military and scientific research personnel of a certain Air Force Testing Base have rooted in the Gobi Desert for 35 years, and built an international standard consolidated test range for China's air weaponry. They also accomplished nearly a thousand scientific research achievements which contributed significantly to bringing China's air weaponry to the international standard.

This air weaponry test base was established in 1958. At present, it has developed into a consolidated testing system equipped mainly with large computers, many modern measuring devices, and command and guidance systems. It undertakes the mission of testing over a hundred types of weapons, including tactical and sophisticated weapons. The base has China's most modern large monitored target range as well as a completely equipped measuring network. The precision of measurement and reliability of experiments have reached international standard.

Since the completion of the base, many thousands of guided missiles have been launched. The base has satisfactorily completed the assignments for every scientific and research experiment, the appraisal, approval, as well as the classification of the "Pili" (Thunderbolt) air-to-air missile series. It has successfully developed and manufactured the "Changkung" (Vast Sky) series high, medium, and low altitude pilotless airplanes as well as performed their test flights. For the first time the base has converted obsolete fighters to remote-controlled drones serving as realistic targets for aeronautic missiles, and air defense missiles; thus, China's long history of relying on import drones is ended. For over 10 times the modified pilotless planes also successfully collected air samples in the mushroom clouds, including those from hydrogen bomb tests in atmosphere. This gathering of valuable data on China's nuclear tests made history in sample collection during nuclear tests. The base also carried out the following important tasks: instrument flight checks of the first and 15 other artificial satellites; as well as flight checks of the first returning satellite airlift, the first long-range freight-rockets, and other different types of rockets. In all, the base has made outstanding contributions to China's aeronautical and aerospace technological development.

The flight test group of the base has successfully test-launched more than 2,000 types of air-to-air missiles; test-flown 11 remote-controlled drones; as well as completed instrument flight checks of the first artificial satellite, and hundreds of flight tests of long-range freight rockets. They were commended on numerous occasions by the Central Military Commission.

Kinetic Model for Initial Sintering Stage of Y-TZP Nanoscale Powder

93FE0761A Beijing GUISUANYAN XUEBAO [JOURNAL OF THE CHINESE CERAMICS SOCIETY] in Chinese Vol 21 No 1, Feb 93 pp 29-32

[Article by Xu Yueping [1776 6490 5493] (correspondent, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai, 200050), Guo Jingkun [6753 2529 0981], Ma Litai [7456 0448 3141], and Ruan Meiling [7086 5019 3781] of the Shanghai Institute of Ceramics, Chinese Academy of Sciences: "Study of Kinetic Model for Initial Sintering Stage of Y-TZP Nanoscale Powder"; MS received 22 Jul 91]

[Excerpts] **Abstract**

Based on the kinetics study of the initial stage of sintering of Y-TZP nanoscale powder, it is found that grain boundary expansion is the main cause of shrinkage in the early sintering stage. The equation of the corresponding sintering kinetics is derived.

1. Foreword

Systematic sintering research aims to establish a kinetic model for the early stage of sintering. Past researchers derived many corresponding models,[1-5] and experiments prove that they were correct to a certain degree. The continuous development of superfine powder (SFP) science makes researchers pay more attention to the study of sintering SFPs. Through theoretical derivation and experimental verification, this paper derives a model of initial-stage sintering so that improved sintering kinetics rules can be established and used as a basis for experiment.

2. Experiment

Y-TZP SFP was made by co-precipitation, then separated by wet colloidal condensation treatment, and subsequently freeze-dried.[6] For discussion, the powder characteristics are listed in the following table:

Characteristics of Powder (700°C, 2h)

Powder	d_{BET}/nm	d_{50}/μm	d^+/nm	AF	Strength of agglomerate/MPa
3Y-TZP	22	0.82	19	37.27	45

In the table: d^+ represents the powder particle size, determined by X-ray broadening; d_{50}, the particle size at the median of weight frequency distribution; and AF = d_{50}/d_{BET}, the agglomerate constant of the agglomerate size. The agglomerate strength is determined by a series of tests to establish the relationship between the green compact density and the pressing pressure. To make the green compact, the powder is first compacted from both directions with a pressure of 200 MPa, and then compacted under a static hydraulic pressure of 300 MPa. Type 402ES-3 dilatometer was used to measure the relationship of the initial-stage compact shrinkage and the sintering time. TEM was used to study the coherency between powder particles.

Before discussing the sintering model, we assume that during sintering, the initial shrinkage stage is defined as when the linear shrinkage rate is less than 5 percent. Because of the minute particle size, the non-agglomerated SFP has large specific surface area, hence, the driving forces during sintering are greatly increased. For example: When the particle configuration is assumed to be spherical, for the 20 nm SFP, the sintering driving force is approximately as follows:

$$\Delta P = 2\gamma/R = 2 \times 0.8/10 \times 10^{-9} = 16 \times 10^7 \text{ N/m}^2,$$

where γ represents surface tension. Under this driving force, the stress in the contacting surfaces among particles is increased. [passage omitted]

4. Conclusion

Based on the mechanism of densification by sintering the Y-TZP SFP, the initial sintering stage model and the corresponding kinetic equation are derived. The model is verified by using real-time measurement of test specimens.

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Study on Microstructure of SiC-Fiber-Reinforced Glass-Ceramic Composite

93FE0761B Beijing GUISUANYAN XUEBAO [JOURNAL OF THE CHINESE CERAMICS SOCIETY] in Chinese Vol 21 No 1, Feb 93 pp 60-65

[Article by Zhu Peinan [6175 1014 0589] (correspondent) of Tongji University, Shanghai, and Huang Shizhong [7806 1102 1813] of Tongji University, and Guo Jingkun [6753 2529 0981], Yang Hanmei [2799 3211 5019], and Zhang Yufeng [1728 3768 1496] of Shanghai Institute of Ceramics, Chinese Academy of Sciences: "Study of Microstructure of SiC-Fiber-Reinforced Glass-Ceramic Composite," funded by Open Laboratory for High-Performance Ceramic Superfine Structures, Chinese Academy of Sciences; MS received 8 Nov 91]

[Excerpts] **Abstract**

The parent glass belonging to the Li_2O-CaO-Al_2O_3-SiO_2 glass-ceramic (GC) system was used as a precursor for the preparation of SiC-fiber-reinforced GC composite. It was first mixed with MgO, then the mixture was sintered to make the matrix for the composite. This method can control the coefficient of expansion of GC matrix to be compatible with that of SiC fiber. The authors used X-ray diffraction analysis to determine the different phase structures in the matrix. TEM was used to examine the microstructures. Fracture surfaces were studied with a SEM. Based on these data, the mechanical properties of the composites are discussed and explained. The experimental results provide recommendations for improved composite technology, hence, production of better composites.

1. Foreword

Among the reinforced ceramic composites,[1] composites of glass-ceramic (GC) matrices with fibers are of special importance, mainly because the expansion coefficients of the matrices can be adjusted to be compatible with the reinforcing fibers by varying the matrices' compositions. For example, a matrix with a GC in the Li_2O-CaO-Al_2O_3-SiO_2 (LCAS) system can be successfully combined with carbon fibers or silicon carbide (SiC) fibers. Composites of these two components have favorable mechanical properties, high temperature properties and chemical stability, thus, a bright future of application in high-tech fields.

In order to master the technology of manufacturing composites and to efficiently promote material characteristics, it is necessary to make a comprehensive study of the matrix composition and microstructure to see how the composite properties are affected.[6] Eventually, based on research results, effective measures for making best composites will be recommended.

2. Experiment

This research aims to study the microstructure of the GC matrix that is compatible with Nicalon SiC fibers and the microstructure of the fracture surface of the composite made with the two components in order to determine the relationship between microstructures and properties.

First, a parent GC in the LCAS system was selected as a precursor. (Parent glass is a pre-manufacturing material. It is mixed with additives and then sintered to make a ceramic matrix. The method of pre-manufacturing the glass material has a wide meaning in ceramic and composite technologies, hence, the pre-manufacturing glass material is called a precursor.) Its composition is: SiO_2, 72.5 percent; Al_2O_3, 25 percent; Li_2O, 3 percent; CaO and other components, balance. Since the starting GC's coefficient of expansion (α_g = 16.7 x 10^{-7} °C^{-1}) is lower than the SiC's (α_f = 30 x 10^{-7} °C^{-1}), new components ought to be added to modify the GC matrix composition and microstructure. Different quantities of MgO were respectively added to the parent glass-precursor. The mixtures were sintered and crystallized according to ceramic technology and made into matrix materials which were subsequently made into specimens for the experiment.

To study the crystal phase composition of the GC, the specimen was made according to the following process: the parent glass is ground into fine powder, pressured into shape, sintered and crystallized. The X-ray diffraction analysis shows that the GC crystal contains mainly the β-spodumene phase (β-quartz solid solution) and the β-cristobalite phase.

The parent glass powder is divided into batches, then mixed with different amounts of magnesium oxide (MgO), respectively. Different matrix materials were made when the mixtures were sintered and crystallized, respectively. X-ray diffractions show that the phases change with the compositions. To use the mixtures as matrix materials, their compositions ought to be gradually adjusted so that their thermal expansion coefficients are modified from 16.7 x 10^{-7} °C^{-1} to about 39 x 10^{-7} °C^{-1}.

Table 1 shows the phases and the thermal expansion coefficients as related to the GC matrix material compositions.

Table 1. Crystalline Phases Formed in Different Glass-Ceramics and the Linear Expansion Coefficient of These Matrix Materials

Sample number	Mass percent of MgO added in glass-ceramics	Crystalline phases formed in sintering or heat treatment	Expansion coefficient of matrix material $\alpha \times 10^{-7}$ °C^{-1}
1	0	β-spodumene, β-cristobalite	16.7
2	5	β-spodumene, clinoenstatite, α-cordierite	19.0
3	9	β-spodumene, clinoenstatite, α-cordierite	33.8
4	12	β-spodumene, clinoenstatite, forsterite, α-cordierite	36.2
5	16	β-spodumene, clinoenstatite, forsterite, α-cordierite	38.7

Experiments show that to achieve the best strength and toughness of the composite, the expansion coefficient of the matrix should be a little lower than that of the SiC fiber (α_f = 30 x 10^{-7} °C^{-1}).[7] To obtain an expansion coefficient similar to that of SiC fiber, different amounts of MgO are added to the parent GCs, respectively. Then, through proper heat treatment processes, these mixtures are made into composite specimens. Flexural test data show that the composite with matrix containing 12 percent of MgO reveals the highest strength.

For microstructure study, a TEM is used to observe the carbon film replicas of these specimens. Figure 1 [photographs not reproduced] shows that the morphology of the GC matrix made directly from the heat-treated parent glass displays uniformly distributed particles of the spodumene type β-quartz solid solution, and β-cristobalite type phase, respectively (Figure 1a). Their average grain size is between 1 and 2 μm. With a small amount of MgO additive, the sintered and crystallized matrix displays columnar clinoenstatite type phase in addition to spodumene phase (Figure 1b,c). As MgO additive increases, the specimen displays very large grain growth in some areas, and also a low crystallization rate in some other areas (Figure 1d). This morphology is probably due to the structural nonuniformity which causes the lack of nucleation dose in the precursor. When the MgO content is raised even higher, the microstructure shows significant decrease of crystallization dose, and consequently large grains result, as shown in Figure 1e. The grains average 5-6 μm in diameter, about 1-2 times larger than those of specimens without additive.

Under a certain temperature condition, a compact specimen is made by hot pressing the GC (which was made by crystallizing the original parent glass) matrix and the SiC fibers. The specimen is tested for flexural strength and fracture toughness. The topography of its fracture surface is observed with a SEM.[8]

Figure 2 [photograph not reproduced] shows that the fibers are apparently extracted from the matrix while the specimen contains 25 volume percent SiC fiber, and the hot-pressing temperature is 1,200°C. The specimen's flexural strength and fracture toughness data are listed as follows:

$$\sigma_b = 478 \text{ MPa}, K_{IC} = 8.4 \text{ MPa-m}^{1/2}.$$

These data are obtained from the composite whose GC matrix expansion coefficient is not compatible with that of the SiC fibers. Hence, the No. 2 material having an expansion coefficient ($\alpha \simeq 20 \times 10^{-7}$ °C^{-1} as shown in Table 1) comparatively compatible with that of the SiC fibers is chosen for the next experiment. A series of specimens made from the composites containing the No. 2 matrix material and different volume percents of SiC fibers, respectively, is used for the experiment. Fracture surface examination discloses that fibers are also extracted from the matrix; additionally, the deviations of cracks are also observed as shown by the arrowhead in Figure 3 [photograph not reproduced]. Figure 4 shows the fracture properties of composites with different volume fractions of SiC fibers.

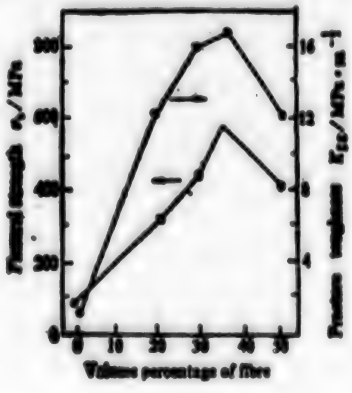

Figure 4. Flexural Strength and Fracture Toughness of Composite vs. the Volume Percent of SiC Fiber Added in Matrix, in the Case of Thermal Expansion Coefficient of Matrix and Fiber Being Well Matched

3. Discussion

The microstructure research findings not only serve to improve the production technology of fiber-reinforced GC composites, but also clarify the mechanism of

ceramic composite technology. Meaningful results from the experiments are discussed as follows:

3.1. This research uses parent GC (or precursor) as starting material, and MgO as additive. The two materials react, forming GC matrix materials, and their phases and the resulting microstructures of the matrix materials are modified accordingly. This finding is new in research and development of composite microstructures. Even more significant, the reaction of MgO and parent glass powders is quite different from that between MgO and crystallized GC powders.[9] This discovery provides a direction in the selection of matrix materials in preparing composites. This method also has good reference value for production of other advanced ceramics.

3.2. The reaction mechanism of MgO and parent GC (precursor) is listed as follows: In the early stage, MgO diffuses easily into the glass structure and precipitates out corresponding β-quartz solid solution (included in the spodumene-cordierite system), and then clinoenstatite and forsterite are formed. However, the clinoenstatite which is formed from the reaction of MgO and β-cristobalite (the second phase in GC) usually cannot diffuse into β-cristobalite solid solution. With the addition of more MgO, forsterite is formed. From this phenomenon, we can deduce that when MgO particles come into contact with parent GC particles, reaction starts at a low temperature stage and that surface diffusion is the basic mechanism. However, when the reaction forms a new phase and its surrounding is still non-crystalline, the reaction will progress in the mechanism of quasi-surface diffusion. [passage omitted]

3.3. After the reaction is completed in the matrix, the materials' phases and microstructures become the main factors affecting the thermal expansion coefficient. When a material is made of mixed phases of different anisotropic expansion coefficients, from the macroscopic point of view, its expansion coefficient is decided by the averaged values according to the phase proportions owing to the randomness of the crystal anisotropys. This observation is especially useful for the GC systems.

3.4. Composites are made by hot-pressing technology from the mixtures of aforementioned matrices and SiC fibers in different proportions. The fracture surface microstructure shows that the optimum portion of fiber is 30 volume percent. For materials with the best combinations of matrices and fibers of compatible expansion coefficients, the degrees of fiber extraction, flexural strength and fracture toughness reach a fairly high standard, but not the highest. Experiments show that as the expansion coefficients of two ingredients get closer, more work is needed to extract fibers from the matrix, and the fracture toughness can also be equivalently improved. In addition, the utilization of heat treatment to increase the interface area between the matrix and fibers will definitely improve the flexural strength and fracture toughness. Further exploration of the above phenomena is a worthwhile project in research on composite microstructures.

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Development of High-Temperature Ceramic Composites

93FE0761C Beijing GUISUANYAN XUEBAO [JOURNAL OF THE CHINESE CERAMICS SOCIETY] in Chinese Vol 21 No 1, Feb 93 pp 77-87

[Article by Shi Keshun [0670 0668 7311], correspondent, Chinese Ceramic Society, Baiwanzhuang, Beijing 100831: "Development of High Temperature Composite Materials"; MS received 19 Jun 92]

[Excerpts] **Abstract**

Based on the requirements for applications above 1,600°C, this paper comments on the current status of high-temperature properties and limitations of structural ceramics and ceramic matrix composites (CMCs). It analyzes and discusses certain directions in high-temperature CMC development, introduces the

key aspects of microcomposite and nanocomposite materials, and briefly introduces functionally gradient materials (FGMs). For applications within the temperature range of 1,204-1,371°C, attention is focused on ceramics and CMCs of reasonable cost. Currently, the most promising materials for 1,600°C and above in the atmosphere are those in the oxide/oxide system, i.e., oxide matrices reinforced with oxide fibers. At present, research on SiC/SiC, and SiC/Si_3N_4 composites is stressed. A composite made by an integrated micro- and nanocomposite technology is probably the [most promising] new concept for the development of materials with super-strength and super-toughness. [passage omitted]

3. Ceramic Nanocomposites and Functionally Gradient Materials

To find a structural material for application at temperatures above 1,600°C, nanoceramics, especially ceramic nanocomposites (CNCs), probably offer an important course to follow.[14,15] It has been proven that the room-temperature hardness and toughness of CNCs are 2 to 5 times those of monolithic ceramics. The high-temperature strength, creep resistance, fatigue failure, and thermal shock resistance of CNCs have been greatly improved. For certain special applications, such as insulation structural materials for 21st-Century aircraft and spacecraft, FGMs may be a candidate.

3.1 CNC Categories

There are two categories of CMCs: microcomposites and nanocomposites (CNCs). In microcomposites, the microscale second phases, such as particles, crystal platelets, crystal whiskers, and fibers, are dispersed along the matrix grain boundaries. The function of such a dispersion is to improve the material fracture toughness.

Nanocomposites are divided into three classes: intra-type, inter-type, and nano/nano-type, as shown in Figure 6. From Figure 6, we can see that the nanoscale particles are distributed either inside the matrix grains (intra-type) or along the matrix grain boundaries (inter-type). The purposes of these distributions are to improve not only the materials' room-temperature mechanical properties and service lives, but also their high-temperature mechanical properties, such as hardness, strength, creep resistance, and fatigue fracture resistance. The nano/nano-type materials are made of nanoscale matrix crystal grains and nanoscale dispersion phases. The nano/nano materials have additional properties, such as fabricability and super-plasticity, similar to those of metals.

3.2 CNC Properties

The earliest CNCs were made by chemical vapor deposition (CVD) technology. CVD technology is a good method for dispersing the second phase into matrix crystal grains, or along the grain boundaries.

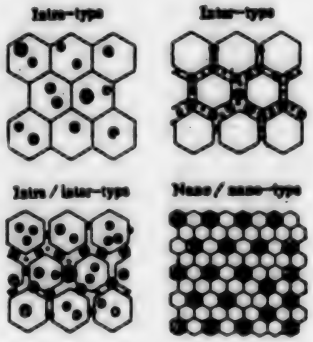

Figure 6. Classification of Ceramic Nanocomposites

However, CVD is not feasible for mass production, and it is costly. To make structural ceramics, sintering technology is more practical. Hirokazu Niibara, using the hot pressing technique (Figure 7) as well as non-pressing sintering and hot isostatic pressing (HIP) technique, successfully made CNCs such as Al_2O_3/SiC, Al_2O_3/Si_3N_4, Al_2O_3/TiC, Mullite/SiC, B_4C/SiC, B_4C/TiB_2, SiC/amorphous SiC, and Si_3N_4/SiC, etc.

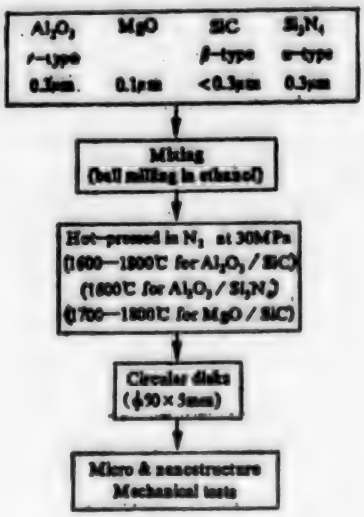

Figure 7. Fabrication Processes of Al_2O_3/SiC, Al_2O_3/Si_3N_4 and MgO/SiC Nanocomposites

Table 3 and Figures 8-12 show the CNC property improvements.

Table 3. Improvement of the Mechanical Properties Observed for the Ceramic Nanocomposites

Composite systems	Toughness K_{IC}/MPa-$m^{1/2}$	Strength σ/MPa	Maximum operating temperature T/°C
Al_2O_3/SiC	3.5 → 4.8	350 → 1520	800 → 1200
Al_2O_3/Si_3N_4	3.5 → 4.7	350 → 850	800 → 1300
MgO/SiC	1.2 → 4.5	340 → 700	600 → 1400
Si_3N_4/SiC	4.5 → 7.5	850 → 1550	1200 → 1400

3.2.1 When 5-volume-percent nanoscale SiC particles are dispersed in the Al_2O_3 matrix grains, the strength of the composite material is about 3 times higher than that of alumina. When the composite is annealed at 1,300°C for 1 hour in atmosphere or inert gas, its strength is further increased to 1,550 MPa (Figure 8).

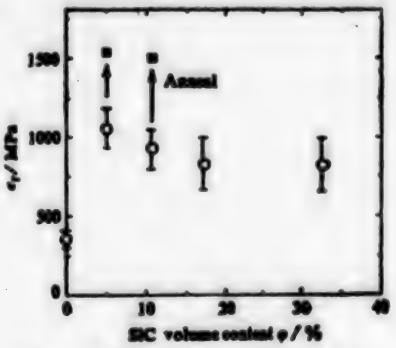

Fig. 8 Improvement of fracture strength by nano-size SiC dispersion for the Al_2O_3/SiC nanocomposites

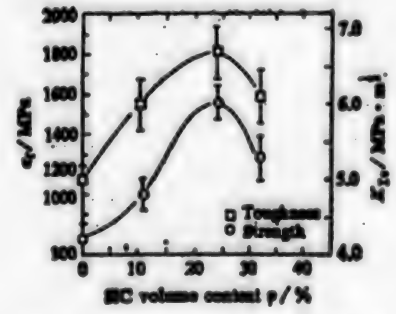

Fig. 9 Improvement of fracture toughness and strength by the nano-size SiC dispersion for the Si_3N_4/32%(vol) SiC nanocomposite

3.2.2 Si_3N_4/SiC CNC is an inter-type CNC. When the SiC content is 25 volume percent, its toughness and strength reach maximum, 6.7 MPa-$m^{1/2}$ and > 1,500 MPa, respectively (Figure 9). The degrees of increases are quite high.

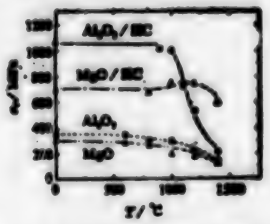

Fig. 10 Temperature dependence of the fracture strength for the Al_2O_3/5%(vol) SiC and MgO/30% (vol) SiC nanocomposites

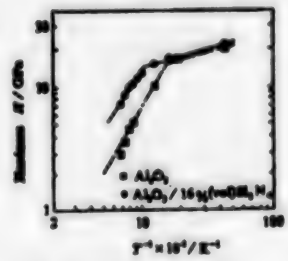

Fig. 11 Variation of Vickers hardness with temperature for the Al_2O_3/16%(vol) Si_3N_4 nanocomposite

Fig. 12 Temperature dependence of fracture strength of the Si_3N_4/32%(vol) SiC nanocomposite

3.2.3 Compared with Al_2O_3 and MgO ceramics, Al_2O_3/SiC, Al_2O_3/Si_3N_4, and MgO/SiC CNCs have much improved strength at temperatures above 1,000°C (Figure 10). The high-temperature strength of MgO/SiC CNC is strikingly improved. The MgO/30-vol%SiC CNC has higher strength in the temperature range 1,000-1,400°C than at room temperature. At 1,500°C, its strength is still close to 600 MPa. From Figure 11, we can see that the CNC's transition point of hardness in reference to temperature (or brittleness to ductility transition temperature, BDTT) is higher than the transition point of monolithic Al_2O_3.

3.2.4 The flexural strength (σ_f) of Si_3N_4/SiC CNC shows no apparent decrease up to 1,400°C. The σ_f of CNC containing 32 volume percent of nanoscale SiC is still above 1,000 MPa; and is about 900 MPa at 1,500°C. In Si_3N_4/SiC CNC, the nanoscale SiC grains disperse both inside the matrix grains and along the grain boundaries, a dispersion pattern different from those of the aforementioned materials.

3.2.5 The SiC/SiC inter-type CNC made from a mixture of SiC powder and polysilastyrene sintered in argon can maintain its strength at temperatures up to 1,500°C. It also has good fabricability similar to that of metals, e.g., thread turning. It is assumed that helical carbon which acts as a lubricant during machining contributes to the fabricability.

3.3 Function of Nanoscale Dispersion Phase

The apparent mechanical property improvements of CNCs, especially oxide CNC, are due to the following reasons: (1) The nanoscale dispersed SiC or Si_3N_4 suppresses the grain growth of the oxide matrix, and inhibits the tendency of excessive grain growth. (2) Local high stresses exist within the dispersion phases and the areas around the dispersion phases. The stresses are induced by the thermal expansion difference between the matrix and the dispersion phases. During cooling, dislocations are generated. The nanoscale particles pierce into or enter the dislocation zones, forming sub-grain boundaries, resulting in the further refining of matrix grains, and consequently the reinforcing of the matrix. (3) The local tensile stress around the nanoscale particle breaks each matrix single crystal in the local area, and the reflex effect between the hard particle and the crack tip promotes local ductility. The breaking modes include intra-grain, or inter-grain, or single-crystal cracking. The changes of grain boundary phases (amorphous phase, almost 10 volume percent of total), which decrease the boundary influence on the high-temperature mechanical properties, significantly improve the high-temperature mechanical properties of the material. (4) The nanoscale SiC particles inhibit the dislocation movement. Consequently, the high-temperature mechanical properties such as hardness, strength, and creep resistance are improved. The improvement of these properties also improves the thermal shock and other thermal mechanical properties.

The function of dispersion phase in Si_3N_4/SiC CNC is obviously different from that in oxide CNC in the following three aspects: (1) When the SiC content is low, during sintering, the nanoscale SiC particles form nuclei for the precipitation of β-Si_3N_4, thus stimulate the growth of fine, slender, and uniformly distributed β-Si_3N_4. This type of grain structure increases material strength and toughness. (2) When the SiC content is high (> 25 percent), the dispersion phase prevents the growth of slender Si_3N_4 grains. Eventually, fine equiaxial Si_3N_4 grains are formed and the material becomes nano/nano-type composite. This type of material has super-plasticity at high temperatures. (3) Nanoscale SiC particles exist along the Si_3N_4 grain boundaries. Although 8 weight percent of Y_2O_3 is added as a sintering booster, impurity phase is not observed between the grain boundaries of SiC and Si_3N_4. This indicates that the dispersion phase and the matrix are directly bonded, which improves the composite's high-temperature mechanical properties and possibly oxidation resistance.

The above discussion shows: CNCs have improved material toughness. High-quality reinforcing ingredients are crucial to the improvement of high-temperature properties. The CNCs' mechanical properties, especially hardness and strength at high temperatures, are significantly improved. Therefore, the development of ceramics with high strength and high toughness will follow the direction of developing a hybrid form of microcomposite and CNC. Next-generation ceramic materials are possibly wafer-reinforced CNCs, as well as crystal-whisker-reinforced CNCs and continuous-fiber-reinforced CNCs. [passage omitted]

4. Concluding Remarks

Ceramics and ceramic composites as structural materials at 1,204-1,371°C have been in application. Obstacles in mass utilization of the materials, especially in the automobile industry, include their high cost. The important research projects are how to ensure their reliability and reduce their cost. For applications in the temperature range 1,371-1,649°C, especially above 1,600°C, current CMCs still have a long way to go. Among the non-oxide/non-oxide CMCs, SiC/SiC, and SiC/Si_3N_4 are the focal materials for certain applications in the temperature range 1,371-1,600°C. For applications above 1,600°C in the atmosphere the most promising course seems to be developing oxide/oxide CMCs, i.e., oxide composites reinforced by oxide fibers. The key is the development of high-quality oxide fibers. The important course that leads to the development of ceramics with super-strength and super-toughness is to integrate the microscale and nanocomposite technologies to create new CMCs. Functionally gradient material (FGM) project will not only produce new materials but also help improve existing materials.

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Chinese Society of Biotechnology Established

93P60313E Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 23 Jun 93 p 2

[Article by Yang Hong [2799 5725]]

[Summary] Another national academic organization, the Chinese Society of Biotechnology, was established in Beijing recently in order to bring together experts in biotechnology area across the nation. The organization will be responsible for sponsoring symposia, promoting academic exchange and cooperation either within China or with foreign organizations, and strengthening biotechnology R&D to promote industrialization to better serve the nation's economy and social development. Some 467 members and 500 representatives from all over the country attended the ceremony. They passed the Chapter of the Society, and elected the first 68 council members. The establishment of the society is a milestone in developing China's biotechnology. It will serve as a "bridge" between research institutes and the industries, and promote conversion of biotechnology results into productivity to invigorate the nation's economy.

New Skin Graft Technique

93P60313D Beijing GUANGMING RIBAO in Chinese 24 May 93 p 1

[Article by Wang Feng [3769 0023]]

[Summary] A research team led by Professor Yue Yi [1471 3015] of the Beijing Posts and Telecommunications Hospital has developed a new technique, a two-staged grafting technique, to treat seriously burned patients. The researchers cultured the allotypic dermal fiber cells and the epidermal epithelial cells separately. They then applied the dermal fiber cells over the wounds first to establish a framework for the new skin and applied the epidermal epithelial over the framework later. New skin grown by this technique was found to be smoother than by the single-staged grafting technique, because of its resemblance to normal skin (i.e., a layer of epidermis over a layer of dermis), and are more rub-resistant. The advantages of this new graft technique is its high utility rate and its short period of recovery. A culture of 1-2 cm^2 allotypic skin will cover an area of about 9 to 10 percent of the body surface after the grafting, and by using this technique, wounds will be healed in 1-3 weeks with little scarring. The method will solve the problem of urgently needed skin resources.

Malaria Vaccine Research

93P60313C Shanghai WEN HUI BAO in Chinese 4 Jul 93 p 3

[Article by Wang Xiaohui [3769 2556 6540]]

[Summary] A breakthrough in malaria vaccine research has been obtained by a graduate student, Pan Weiqing [3382 5898 1987], of the Institute of Biotechnology and Molecular Genetics of the Second Military University. Under the instruction of his advisor Lu Deru [7120 1795 1172], Pan Weiqing used the advanced genetic engineering techniques to conduct immune protection and antigen variability research on two candidate antigens, and preliminarily identified the elements that constitute the antigens. Pan Weiqing has been the first researcher to reveal the gene recombination characteristic of antigens he obtained from five Plasmodia found in China. He also revealed the nature of variation of the antigens, successfully sequenced the functional genes of the five strains of Plasmodia, and found that variation of amino acid occurred in functional genes of all five strains. His achievement is an important approach to the development of effective malaria vaccines, and a breakthrough in finding ways to control malaria infection.

Gene Therapy Research Center Established in Shanghai

93P60313B Shanghai WEN HUI BAO in Chinese 10 Jul 93 p 1

[Article by Kang Mingqin [1660 2494 3830] and Hu Derong [5170 1795 2837]]

[Summary] Recently China's first gene therapy research center was jointly established in Shanghai by the Shanghai No. 2 Medical University, the Shanghai Immunology Research Institute and the Ruijin Hospital. In 1994 the center will begin clinical treatment of overseas Chinese suffering from malignant tumors. On the basis of molecular biology, replacing the malfunctioning genes with normal genes will be adopted in the center.

Fermentation Technology Using Immobilized Yeast Cells

93P60313A Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 23 Jun 93 p 2

[Article by Wang Lichao [3769 4539 2600] and Chen Huiming [7115 1920 2494]]

[Summary] A technique using immobilized yeast cells to produce alcohol in the fermentation industries has been jointly developed by the Institute of Biology of the Gansu Academy of Sciences and Longxi Alcohol Manufacturing Plant. The technique will greatly enhance the production of alcohol by 4 percent and cut consumption of foodstuff by 400 million kilograms (4 percent). In 1987, the Gansu Academy of Sciences started the research on using polyvinyl alcohol to immobilize the yeast cells, which resulted in producing nontoxic, highly bacteria- and rub-resistant, and long-lasting immobilized yeast cells. The technique was first tested in a 2 cubic-meter canister and then tested 30 times in a 100 cubic-meter fermenter for alcohol production.

Characterization of Single Ion Channels Formed by Fragment B of Tetanus Toxin in an Artificial Lipid Bilayer

40091015O Beijing SHENGWUHUAXUE YU SHENGWUWULI JINZHAN [PROGRESS IN BIOCHEMISTRY AND BIOPHYSICS] in Chinese Vol 20 No 2, Apr 93 pp 115-119

[English abstract of article by Lei Dianliang [7191 3013 5328] of the National Institute for the Control of Pharmaceutical and Biological Products, Beijing, N. Sigimoto and M. Matsuda of the Research Institute of Microbial Diseases, Osaka University, Japan]

[Text] The purpose of this study is to find out how tetanus toxin enters into the target cells and its function in target cells in inhibiting the release of neurotransmitter. The ion channel formation of fragment B of tetanus toxin in an artificial lipid bilayer was described. Fragment B with a molecular weight of 48,000 was purified by fast protein liquid chromatography. The channel activities were recorded from an asolectin bilayer membrane by patch clamp technique. It rarely formed ion channels at neutral or acidic pHs. In contrast, with pH gradient the channel activities of fragment B were easily recorded. By analysis of single channels formed by fragment B, the conductance of the channel was 2.3 pS. At different holding potentials (-100-+150 mV) the channels gave same conductance, it indicated that "the fragment B channel" passed K ion in both directions. The opening-time of the channel was maintained at 20-40 and 100-120 ms, and the closing-time of it was main at 20 ms. These results indicated that the channel of fragment B was rapidly flickering between the states of opening and closing.

Experimental Study of Corneal Endothelial Damage by Nd:YAG Laser

40091015N Beijing ZHONGHUA YANKE ZAZHI [CHINESE JOURNAL OF OPHTHALMOLOGY] in Chinese Vol 29 No 3, May 93 pp 180-182

[English abstract of article by Li Xiaoling [2621 2556 7117], He Shouzhi [0149 1343 1807], Hao Yanxia [6787 3601 7209], et al. of the Department of Ophthalmology, PLA General Hospital, Beijing]

[Text] Evaluation by scanning electron microscopy revealed that rabbit eyes that underwent experimental anterior capsulotomy by Q-switched Nd:YAG laser suffered no endothelial damage, while the endothelium was focally denuded in those that received laser shots focused within 0.8 mm behind it, and the Descemet's membrane was disrupted by laser shots focused at the endothelium. The implications of clinical laser application is that it is safe to use if the laser shots focus on

Efficacy of Argon and Nd:YAG Laser Combined in the Treatment of Primary Chronic Closed-Angle Glaucoma

40091015M Beijing ZHONGHUA YANKE ZAZHI [CHINESE JOURNAL OF OPHTHALMOLOGY] in Chinese Vol 29 No 3, May 93 pp 146-148

[English abstract of article by Xing Yiqiao [6717 1837 2890], Sun Xinfu [1327 0207 1318], and Liu Jinman [0491 6855 3341] of the First Affiliated Hospital of Hubei Medical University, Wuchang]

[Text] Twenty-two cases (29 eyes) of primary chronic closed-angle glaucoma were treated with Argon laser gonioplasty (ALG) and Nd:YAG laser iridectomy. Among 8 eyes in which the closed-angle failed to be opened by ALG, Nd:YAG laser gonioplasty was added, and 6 eyes became successful. For 9 eyes in which the IOP failed to drop in spite of the opened anterior chamber angle, Argon laser trabeculoplasty was added to bring remarkable curative effects to 7 eyes. During a follow-up of 5 to 14 months, 25 eyes (86 percent) obtained satisfactory results.

Studies on Preparation Technology of Microspheres of Contraceptives

40091015L Beijing YAOXUE XUEBAO [ACTA PHARMACEUTICA SINICA] in Chinese Vol 28 No 4, Apr 93 pp 296-301

[English abstract of article by Lei Yong [7191 3057] (Master degree post-graduate) and Lu Bin [7120 1755] of the School of Pharmacy, West China University of Medical Sciences, Chengdu]

[Text] Contraceptive poly ethylglycol-lactide (PEGL), a Chinese-synthesized biodegradable polymer microsphere was prepared by a solvent evaporation process using levonorgestrel (LNG) and estradiol (E_2) as model drugs and PEGL as the core material. The experimental conditions were optimized, the mean volume diameter obtained being 30 μm and rate of encapsulation 75-82 percent. In vitro, it was found that the drug release rate decreased with decreasing drug content in the microspheres. The microspheres of the contraceptive maintained anticonception duration in mice for over 6 months, indicating that the microspheres have remarkably long acting sustained release action.

The Physical Properties, Pharmacology and Antifertility Action of Crystal Trichosanthin Protein Liposome

40091015K Beijing YAOXUE XUEBAO [ACTA PHARMACEUTICA SINICA] in Chinese Vol 28 No 4, Apr 93 pp 290-295

[English abstract of article by Zhang Xiucheng [1728 4423 2052] of Liaoning Academy of Traditional Chinese Medicine Research, Shengyang, Li Wei [2621

Shenyang, and Wu Qiang [0702 1730] of Liaoning Institute of Family Planning Research, Shenyang]

[Text] The crystal trichosanthin protein liposome (TPL) was prepared by an emulsion-forming method. The rate of entrapment was 33.0-44.8 percent and the rate of recovery was 95.15-99.58 percent. The determination of trichosanthin protein was accomplished by spectrophotometry at 650 nm, thus eliminating completely the interference of lipids. The distribution of particle size of TPL was mainly in the range of 1-2 μm (96.9 percent). TPL was sterilized by ^{60}Co radiation at 4°C for 90 min and was stable when stored at 4°C, 25°C and 37°C. The seepage rate of trichosanthin from the liposome was 15.22 percent after storage for 38 days at room temperature. Experiments showed that TPL had a slight allergic reaction, but was safe by hemolysis and coagulation tests. When the mice were given TPL in 8 μg per animal 6 days after pregnancy, the rate of termination of early pregnancy was 83.3 percent. It thus appears that TPL can terminate early pregnancy in mice distinctly. This indicates that TPL may be expected to be developed into a new type of anti-early pregnancy preparation.

Synthesis and Bio-Activity of Coumarin Derivatives and Studies on Its Relationships Between Activity and Lipophilicity

40091015J Beijing YAOXUE XUEBAO [ACTA PHARMACEUTICA SINICA] in Chinese Vol 28 No 4, Apr 93 pp 266-272

[English abstract of article by Wu Kun [0702 1024], Tong Zengshou [4547 2582 1108], et al. of the Institute of Radiation Medicine, Academy of Military Medical Sciences, Beijing 100850]

[Text] 4-Methyl-7-hydroxy-6 or 8-allylcoumarin, a new type of radioprotectors, has poor solubility in water and in oil, which influences markedly its absorption in body and effectiveness of oral administration. For improving its solubility, 14 coumarin derivatives were synthesized on the basis of increasing its hydro- or lipophilicity, and studied preliminarily on their toxicities, radioprotective activities, and relations between their hydro- or lipophilicity and activities. It is found that both compounds (5a, 6a), can be dissolved in ethyl oleate and the latter in water partially as well, retain the radioprotective activities basically, and improve the survival of 65 percent ($P < 0.01$) of mice exposed to 9.0 Gy $^{60}Co\gamma$-ray when administered before irradiation. In synthesis, von Pechmann reaction was improved; 6-allyl intermediate was synthesized by the method of blocking the 8-position by iodine, and the process was studied. Mannich base was synthesized under high pressure by using CH_2Cl_2 as C_1 synthon. [followed by Scheme 1]

Ribozyme That Cleaves Site-Specifically the RNA Fragment Derived From Core Antigen Gene of Hepatitis B Virus in Vitro

40091015I Beijing SHENGWUHUAXUE YU SHENGWUWULI XUEBAO [ACTA BIOCHIMICA ET BIOPHYSICA SINICA] in Chinese Vol 25 No 3, May 93 pp 313-317

[English abstract of article by Zhu Laifa [4555 0171 4099], Lu Changde [7120 7022 1795], et al. of the Shanghai Institute of Biochemistry, Academia Sinica, 200031]

[Text] According to the basis of "hammerhead structure" summarized by Symons a ribozyme in length of 38 nucleotides for site-specific cleavage of RNA fragment derived from core antigen (HBcAg) gene of Hepatitis B virus (HBV) was designed and synthesized. The RNA fragment used as substrate was obtained by transcription with T_7 RNA polimerase from plasmid which contains T_7 Promoter and part of the HBcAg gene. The results show that the RNA fragment can be cut site-specifically by the designed 38 mer ribozyme to yield two products. The relationship between cleavage percentage and temperature and time in the reaction were determined. The Km and Kcat value for this reaction are 0.74 μm and 0.85 min^{-1} respectively.

Key words: Hepatitis B virus; Ribozyme; Site-specific cleavage

Study on the Anticoagulation Factor (ACF) From *Agkistrodon acutus* Venom by Raman Spectra

40091015H Beijing SHENGWUHUAXUE YU SHENGWUWULI XUEBAO [ACTA BIOCHIMICA ET BIOPHYSICA SINICA] in Chinese Vol 25 No 3, May 93 pp 281-286

[English abstract of article by Liu Qingliang [0491 3237 0081], Xu Xiaolong [1776 2556 7893], and Wang Chun [3769 3196] of the Department of Applied Chemistry, University of Science and Technology of China, Hefei]

[Text] The secondary structure of the anticoagulation factor (ACF) both in solution and in powder form has been investigated by Raman spectra. ACF in aqueous solution consists of 56.1 percent β-sheet 17.2 percent α-heliex and 26.6 percent as random coils when calculated by the method of Lippert et al. The lyophilization of ACF does not give the effect on the microenvironment of tryptophan and tyrosine residues, but affects the peptide-backbone structure. The results determined by Raman spectra are consistent with the conclusion analyzed by other methods.

Key words: Raman spectra; anticoagulation factor

SA Liposomes: A Highly Efficient Reagent Mediating DNA-Transfection

40091015G Beijing SHENGWUHUAXUE YU SHENGWUWULI XUEBAO [ACTA BIOCHIMICA ET BIOPHYSICA SINICA] in Chinese Vol 25 No 3, May 93 pp 231-238

[English abstract of article by Yang Jingping [2799 7234 1627], Kong Yuying [1313 3768 5391], et al. of the State Key Laboratory of Molecular Biology, Shanghai Institute of Biochemistry, Academia Sinica]

[Text] SA (stearylamine) liposome was prepared from stearylamine, a natural cationic lipid, and dioleoylphosphatidylethanolamine. SA facilitates the interaction of liposome-DNA complex with cultured cells, resulting in above 90 percent CV-1 cells interacted with lipid-DNA complex by labeling SA Liposomes with N-NBD-DPPE and N-Rh-DPPE. When SA Liposomes mediated transfer of pCH110, pSV2cat, pS100 and pTK-Luc plasmid DNA to CV-1 cells, the DNA expression is 10 to 40-fold more effective than calcium phosphate, and 5 to 10-fold more effective than Lipofectin reagent. Moreover, its cytotoxicity was only one fourth of that of Lipofectin reagent. The technique is simple, highly reproducible. SA Liposomes are cheap and easily prepared.

Key words: Stearylamine (SA) Liposomes; Gene; Transfection

Studies on Crystal Structure of A21Gly-Human Insulin Mutant at 2.6 Angstrom Resolution

40091015F Beijing SHENGWUHUAXUE YU SHENGWUWULI XUEBAO [ACTA BIOCHIMICA ET BIOPHYSICA SINICA] in Chinese Vol 25 No 3, May 93 pp 223-229

[English abstract of article by Huang Weijun [7806 0251 6511], Jin Lei [6855 7191], Zhang Ying [1728 5391], and Wang Dacheng [3769 1129 2052] of the Institute of Biophysics, Academia Sinica, Beijing, and L. Langkjaer and J. Markussen of Novo Institute, Novo Alle, 2880 Bagsvaerd, Denmark; project is supported by the State High-Tech Development Foundation and the UNIDO Grant]

[Text] The chemical stability of human insulin is directly related to the residue of A21-Asn at the A chain C-terminal and can be distinctly increased by substituting for the A21 residue through protein engineering. But A21-Asn has been conserved throughout evolution and is invariant among the insulin species known today. In order to understand the impact of A21-substitutions on the molecular structure, X-ray crystal structure analysis for a series of A21 mutants was undertaken.

The crystal structure of Gly^{A21}-Human insulin, a highly stable mutant prepared by site-directed mutagenesis, was determined by X-ray analysis at 2.6 Angstrom resolution. The structure was refined by an energy restrained least-square technique, programmed in EREF, with a final agreement factor R = 0.151 and a r. m. s bond-length deviation 0.019 Angstrom. On the final ($2F_o$-F_c) map, mutant residue Gly^{A21} can be specified definitely. Except the A chain C-terminal, the general conformation of the mutant molecule is very similar to that of the native insulin. The main changes of conformation appeared on a local area at A chain C-terminal, but the hydrogen bond between NH-A21 and CO-B23 is still kept in both individual molecules. The structural basis of the chemical stability and the biological activity of the mutant was discussed.

Characterization of cDNA and Genomic Structure of Arrowhead Proteinase Inhibitors A and B

40091015E Beijing SHENGWUHUAXUE YU SHENGWUWULI XUEBAO [ACTA BIOCHIMICA ET BIOPHYSICA SINICA] in Chinese Vol 25 No 3, May 93 pp 207-215

[English abstract of article by Xu Wenfeng [6079 2429 1496], Gong Zhenzhen [7895 5550 5550], and Qi Zhengwu [2058 2973 2976] of the National Molecular Biology Lab, Shanghai Institute of Biochemistry, Academia Sinica, and Tao Weikang [7118 4850 1660] of the Department of Biochemistry, the Second Military Medical University, Shanghai; project is supported by the State Biotechnology Foundation]

[Text] Based on the determined amino acid sequences of arrowhead double-headed proteinase inhibitors A and B, the arrowhead cDNA library was constructed. Using the total cDNA as a template to amplify three cDNA fragments of the inhibitors in vitro by the PCR method, the full-length cDNA sequences were then ascertained. The open reading frame encodes the pre-inhibitor, including the 24-residue signal peptide. It is worth pointing out that both cDNA of inhibitors A and B contain an 87 bp intron in the AA[down arrow]G codon of residue Lys (97). The deduced amino acid sequences are consistent in principle with those determined by primary structure analysis, except that there are seven extra residues at the C-terminal part of the inhibitors, which might be cleaved off by protease postprocessing right after gene expression. According to the elucidated cDNA sequences, the structural genes of inhibitors A and B were amplified by the PCR method with the total cDNA and genomic DNA of the arrowhead as a template, respectively. Sequence analysis indicated that the genomic DNA of the inhibitors A and B have the same sequences as their cDNA.

The Construction of Immunotoxin Containing Momordin Against Human Bladder Carcinoma and in Vitro Cytotoxicity

40091015D Beijing ZHONGHUA WEISHENGWUXUE HE MIANYIXUE ZAZHI [CHINESE JOURNAL OF MICROBIOLOGY AND IMMUNOLOGY] in Chinese Vol 13 No 3, Jun 93 pp 176-178

[English abstract of article by Zhao Chong [6392 5039], Xie Shusheng [6200 5771 3932], et al. of the Department of Immunology, Beijing Medical University]

[Text] To construct an immunotoxin (IT) against human bladder carcinoma, a ribosome inactivating protein-Momordin (MT) was covalently linked to a monoclonal antibody BDI-1, which recognized a determinant expressed on human bladder carcinoma cells BIU-87 and E-J, by heterobifunctional reagent SPDP. The conjugates BDI-1-MT were purified on Sephadex G-100 column and Blue-Sephadex affinity column. The part of BDI-1-MT was selected for further analysis. The results of indirect immunofluorescent test showed that BDI-1-MT was retained very high antibody activity. The in vitro cytotoxicity assays indicated that the immunotoxin is a potent and specific cytotoxic agent for human bladder carcinoma. It killed the target cells BIU-87 and E-J cells by 50 percent at concentration of 9×10^{-10} and 7.5×10^{-10} mol/L, respectively. But no apparent cytotoxic activity was observed to non-targeted Lovo, a human colon carcinoma cell line, at concentration of 5×10^{-7} mol/L.

Key words: Monoclonal antibody immunotoxin; Momordin; Bladder carcinoma

Study on Immunogenicity and Protective Immunity Induced by OMP of Salmonella Typhimurium

40091015C Beijing ZHONGHUA WEISHENGWUXUE HE MIANYIXUE ZAZHI [CHINESE JOURNAL OF MICROBIOLOGY AND IMMUNOLOGY] in Chinese Vol 13 No 3, Jun 93 pp 156-159

[English abstract of article by Li Fusheng [2621 4395 0524], Zhao Fenglan [6392 7685 5695], et al. of the Department of Microbiology, Henan Medical University]

[Text] The study was undertaken to assess the ability of the outer membrane proteins (OMP) of *S. typhimurium* to induce protection against challenge of the bacteria. OMP were isolated as described by Schnaitman and it has been found that 36-41 kD were the major bands of OMP in SDS-PAGE. OMP were proved to be good immunogen in mice (1:2560). Furthermore, mice immunized with OMP exhibited significant levels of delayed-type hypersensitivity response. An anti-serum obtained from rabbits reacted mainly against the bands of the molecular weights corresponding to the so-called porins as shown by Western blot. Immunization with as little as 50 μg of OMP conferred 100 percent protection to mice challenged with up to 500 lethal doses (LD_{50}). The role of LPS contained in OMP was also evaluated. All these results indicate that because the OMP could induce active immunity against the infection of Salmonella and the OMP would be a candidate of vaccine.

Key words: OMP; *Salmonella typhimurium*; Protective immunity

Identification of DNA Probes for *B. Fragilis* and Detection of *B. Fragilis* in Specimens From Infected Animals With Identified Probe

40091015B Beijing ZHONGHUA WEISHENGWUXUE HE MIANYIXUE ZAZHI [CHINESE JOURNAL OF MICROBIOLOGY AND IMMUNOLOGY] in Chinese Vol 13 No 3, Jun 93 pp 152-155

[English abstract of article by Li Jianbiao, et al. of the Institute of Microbiology and Epidemiology, Academy of Military Medical Sciences, Beijing]

[Text] Eight Hind III fragments of chromosomal DNA randomly cloned from *Bacteriodes fragilis* (ATCC 23745) were labelled with ^{32}P by nick translation. A species-specific DNA probe (pBF-15) for *B. fragilis* and two type 1-specific probes (pBF-19 and pBF-21) were obtained by screening of these fragments with international standard Bacteriodes strains. The limit of detection for these probes was 3.8×10^6 bacteria. *B. fragilis* with pBF-15 could be detected if it comprised 14 percent of the mixture. Eight specimens from infected animals were directly tested for *B. fragilis* by hybridization, and the results were in concordance with those of conventional method.

Key words: *B. fragilis*; Hybridization; Animal model

Specific IgE Type and IgD Type Circulating Immune Complexes in Sera of Patients With Epidemic Hemorrhagic Fever

40091015A Beijing ZHONGHUA WEISHENGWUXUE HE MIANYIXUE ZAZHI [CHINESE JOURNAL OF MICROBIOLOGY AND IMMUNOLOGY] in Chinese Vol 13 No 3, Jun 93 pp 137-139

[English abstract of article by Yang Dongliang [2799 2639 0081], Wang Youkun [3076 3945 0981], et al. of the Clinical Immunology Research Unit, Tongji Hospital, Tongji Medical University, Wuhan]

[Text] The microtitre plates were coated with rabbit anti-human IgE and IgD and then the capture ELISA were established for the detection of specific IgE type or IgD type circulating immune complexes in the sera of patients suffering from epidemic hemorrhagic fever. The results of experiment with 263 sera samples of EHF patients showed that the detected rates of specific IgE type and IgD type CIC were 61.98 percent and 49.05 percent. The dynamic changes of the detected rates of the two types CIC were similar, i.e., higher in early stage and highest in the 4th-8th day after the onset of illness. A close correlation between the severity of patients and the positive rate of the two type CIC also was found.

Key words: Epidemic hemorrhagic fever; Specific IgE; Specific IgD; CIC

Galaxy-II Supercomputer's FORTRAN Compiling System Highlighted

93P60316C Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 28, 21 Jul 93 pp 11, 13

[Article by Yang Taolan [2799 3165 3482] of the Computer Institute, University of Science and Technology for National Defense: "Examining the Nation's Supercomputer Software Progress From Viewpoint of Galaxy-II's FORTRAN Compiling System"]

[Summary] The Galaxy-II (or YH2) supercomputer's performance is similar in several respects to that of the Cray X-MP—a type of supercomputer frequently used for weather forecasting, petroleum exploration, and theoretical physics calculations. These applications programs all have FORTRAN compiling systems written in several hundred thousand to several million lines of code.

In the past year or so, over 20 domestic research units have tested the YH2 with about 1,000 routines, totaling over 1 million lines of FORTRAN, for large and mid-sized problems, including four or five major Benchmark test programs frequently run worldwide. Scientists from the State Meteorological Center (SMC) have run a mid-range [i.e., 5-7-day] weather forecast—a FORTRAN routine requiring over 100,000 lines of code—and noted that this weather forecast which originally required 1,100 seconds [on earlier high-performance computers] only took 413 seconds on the YH2. This prompted one SMC computer expert to remark that the "YH2 system software's corresponding performance meets or exceeds that of the Cray X-MP." At the formal state appraisal of the YH2 [last November], the technical experts noted that the YH2's FORTRAN compiling system on the whole matches mid-to-late-80s international standards, and that in some respects it matches [early 90s] state-of-the-art. To give one example, one SMC weather forecast simulation run on the YH2 indicated a two-processor speedup of 1.885, while the equivalent two-processor speedup for this simulation run on a Cray X-MP has been measured at 1.76.

Open Multiprocessor System Marketed

93P60306A Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 24, 23 Jun 93 p 2

[Article by Fang Heming [2455 7729 6900]: "Huanan Markets Open Multiprocessor System"]

[Summary] The Huanan 6220 open multiprocessor system developed by the Huanan [i.e., "South China"] Computer Corp. passed expert technical appraisal the other day, and is now in batch production. The Huanan 6220 comes with 486 chips for its CPUs, 16 MB of DRAM for main memory, 4 MB of floppy disk cache memory, 40 serial interfaces, two parallel interfaces, an Ethernet board, an SCSI [small computer systems interface] intelligent controller, and disk and tape peripherals. The multiprocessor architecture, providing a performance of 20-190 MIPS, is based on the enhanced 32-bit high-speed EMC bus, which has three times the speed of the EISA [extended industry standard architecture] bus. Up to 200 users can be put on line with this open system.

Multiprocessor Simulation Computer Certified

93P60316B Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 28, 21 Jul 93 p 1

[Article by Li Hongfang [2621 1347 5364]: "High-Speed Mini Parallel Simulation Computer Developed"]

[Summary] The nation's first high-speed mini parallel simulation computer, the MPSC-1 (Multiprocessor Simulation Computer #1), jointly developed by Northwest Polytechnical University [in Xian] and by the Second Artillery Corps' Engineers Institute, recently passed expert appraisal. This system is designed for high-precision real-time dynamic simulation of complicated phenomena occurring in strategic missile control systems during missile flight. The system incorporates 80s-era VLSI high-speed chips and a parallel architecture. The multiprocessor architecture is built around eight high-speed CPUs providing a peak operating performance of 40 MIPS. Operating precision for yaw-channel main output tolerance full-scale error is 3-5 parts per thousand (i.e., 0.3-0.5 percent).

Intelligent Computer Research Advances, Goals Highlighted

93P60316D Beijing RENMIN RIBAO OVERSEAS EDITION in Chinese 29 Jul 93 p 3

[Article by Zhu Youdi [2612 1635 2769]: "New Advances in Nation's Research on Intelligent Computers"]

[Summary] Beijing, 28 Jul (XINHUA)—The nation's "intelligent computer systems" research has achieved major advances. This research is a core component of the State High-Tech Research and Development Plan approved and being implemented by the Central Government. Over 90 percent of the 100-odd projects in this plan—which is centered on computers, microelectronics, and telecommunications—are proceeding according to or better than the plan. The State has targeted "Intelligent Computer Systems" as one of the three major topics in information research, and is organizing efforts toward the strategic goal of developing by 1995 a series of high-performance systems possessing elementary intelligent behavior and oriented toward intelligent applications. For this reason, selected artificial intelligence (AI) software systems and high-performance AI workstations are being emphasized, especially those with intelligent interfaces able to process Chinese characters. The goal by 2000 is to basically develop a set of integrated intelligent computer systems with calculation, perception,

memory, inference, and learning functions and with abundant software and production capacity. The parallel graph reduction intelligent workstation [developed by Qinghua University—see JPRS-CST-92-014, 24 Jul 92 p 26] and the [Galaxy] Intelligent Tool Computer [see JPRS-CST-93-007, 21 Apr 93 p 13] are examples of AI-oriented hardware and software already developed as part of this [863] High-Tech Plan.

Ministry of Electronics Industry Institute 6, Sunsoft Reach OEM Agreement

93P60306B Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 25, 30 Jun 93 p 1

[Article by Xiao Yan [2556 3601]: "Ministry of Electronics Industry's Institute 6 and Sunsoft Reach OEM Agreement"]

[Summary] On 24 June, the U.S. firm Sunsoft Corp. and the Ministry of Electronics Industry's (MEI) Institute 6 reached a formal agreement on an OEM [original equipment manufacturer] relationship. MEI Institute 6's Huasheng [Huasun] Co. in OEM mode will import Sunsoft's software products, including Solaris operating system environments for SPARC platforms and Intel X86 platforms; simultaneously, Institute 6 will act as Sunsoft's first OEM agent in China, including servicing Sunsoft's products in China.

Domestically Made LCD Pen-Input Computer Unveiled

93P60306C Beijing ZHONGGUO DIANZI BAO [CHINA ELECTRONICS NEWS] in Chinese 5 Jul 93 p 1

[Article by Li Wansang [7812 8001 2718]: "'Pen-Input Computer' Unveiled"]

[Summary] The state-of-the-art liquid crystal display (LCD) pen-input computer jointly developed, produced, and marketed by the Shantou Ultrasonic Electronics Group and Hong Kong's Jianbi [4608 4581] International Ltd. was recently put into batch production. This LCD pen-input computer has a high (over 98 percent) discrimination [i.e., recognition] rate and high recognition speed (less than 0.5 second per character). This product was designated as a Shantou Municipal New & High-Tech Development Zone priority project and municipal Torch Plan project, and was supported by the Municipal Science & Technology Commission. The joint venture Shantou-Jianbi Ltd. was formed with an investment of HK$18 million to manufacture this product; annual production capacity is 10,000 units.

Database-Language-Oriented Supervisory Software Automatic Generator Developed

93P60316A Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 16 Jul 93 p 2

[Article by Miao Qing [5379 7230]: "Database Language/SQL Applications-Oriented Supervisory Software Automatic Generator Developed"]

[Summary] Computer scientists at Beijing University of Aeronautics and Astronautics (BUAA) have developed a new software product, ESQLAG2.0, which is an "integrated rapid development automatic generator oriented toward standard database language and SQL [structured query language] applications." This high-performance microcomputer database tool is designed as a SQL applications generator and 4GL [fourth-generation language] development too, and can be relatively easily transported to minicomputer and workstation environments. This BUAA-developed state-of-the-art database tool has been formally certified by the Ministry of Aerospace Industry.

Shanghai Institute Develops New Operating System

93P60306D Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 26, 7 Jul 93 p 1

[Article by Yu Gan [3022 0051]: "Shanghai Develops Microcomputer Real-Time Multitasking Operating System"]

[Summary] The Shanghai Computing Institute recently announced its development of the SRMX real-time multitasking operating system for microcomputer platforms. The SRMX's required operating environment is an 8086/8088 or 80286/80386/80486-CPU microcomputer. Support software is PC DOS 3.0 or higher, and at minimum the system comes with IBM or Microsoft PC DOS macroassembler language.

Tb-Ga-Garnet Crystal Developed by CAS Institute of Physics

93P60315A Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 16 Jul 93 p 1

[Article by Huang Xingzhang [7806 5281 4545]: "Institute of Physics Develops Terbium-Gallium-Garnet Crystal"]

[Summary] Scientists at the CAS Institute of Physics here in Beijing have grown the first domestic high-quality terbium-gallium-garnet (Tb-Ga-garnet) crystal. This crystal, synthesized via a vertical pulling technique, has been shown to be an excellent material for visible-wavelength and near-IR-wavelength optical isolators and modulators. Up to now, only one company in the United States has been able to make and sell this crystal, at a high price. Testing of the domestically made product shows that its optical quality meets that of the foreign-made product; moreover, it sells for a lower price.

980-nm Ti-Gem Laser Pumped Fiber Optic Amplifier Gain Reaches 49.6 dB

93P60315B Beijing ZHONGGUO KEXUE BAO [CHINESE SCIENCE NEWS] in Chinese 21 Jul 93 p 2

[Article by Peng Dejian [1756 1795 1696]: "980-Nanometer Titanium-Gem Laser Pumped Fiber Optic Amplifier Gain Reaches 49.6 dB"]

[Summary] Hefei (ZHONGGUO KEXUE BAO wire report)—Scientists at the University of Science and Technology of China (USTC) and at the CAS Anhui Institute of Optics and Fine Mechanics (AIOFM), on the basis of earlier 800-nm EDFA (erbium-doped fiber amplifier) research, recently reported an EDFA gain of 49.6 dB with a 980-nm-wavelength Ti-gem laser as the pump source. Specifically, when a 38-nanowatt optical signal passed through this EDFA, the net output power measured 3.48 milliwatts (mW), or a net gain of 49.6 dB. The appraisal experts noted that this parameter is at the worldwide state-of-the-art. Other critical performance indicators are: maximum gain factor is 5.4 dB/mW, and maximum power output is 5.10 mW.

Ministry of Electronics Industry Institute 44 Passes Military QC Inspection

93P60309B Beijing ZHONGGUO DIANZI BAO [CHINA ELECTRONICS NEWS] in Chinese 30 Jun 93 p 2

[Article by Yu Ruming [0151 3067 2494]: "Institute 44 Passes Defense Industry Appraisal"]

[Summary] The optoelectronic products manufactured by the Ministry of Electronics Industry's Institute 44 were formally certified on 28 May to be in compliance with the "Defense Industry Product Quality Management Regulations." These products include 200 varieties of CCDs, semiconductor light-emitting devices and detectors, fiber optic gyros, integrated optical waveguides, optoelectronic integrated circuits, and similar devices with applications in aerospace, armaments, warships, and other electronics-related fields.

10,000-G Rate Gyro Developed

93P60309A Beijing ZHONGGUO DIANZI BAO [CHINA ELECTRONICS NEWS] in Chinese 30 Jun 93 p 1

[Article by Luo Ping [5012 1627]: "Rate Gyro Able To Withstand High Impact, High G Force Developed"]

[Summary] A high-impact angular velocity gyro able to withstand a force of 10,000 Gs has been developed by the Ministry of Electronics Industry's Institute 26. This gyro, to be used in National Defense key projects, has been successfully tested in equipment sets at various Ordnance Industry Corporation units. The product also opens up the new field of piezoelectric gyro applications.

Study of GaAs Symmetric Directional Coupler Switch

93FE0759A Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 14 No 5, May 93 pp 286-291

[Article by Feng Hao [7458 3158], Li Xihua [2621 6932 5478], Wang Minghua [3769 2494 5478], and Wu Zhiwu [0702 1807 2976] of the Department of Information and Electronic Engineering, Zhejiang University, Hangzhou: "Study of GaAs Symmetric Directional Coupler Switch"; MS received 25 Nov 91, revised 5 Mar 92, supported by the National Natural Science Foundation]

[Text] **Abstract**

The development of a GaAs symmetric directional coupler switch is reported. The operating principle of the device and causes for crosstalk are analyzed. A self-registering technique is realized for the first time to minimize electrode registration error. The switching characteristics of the device are tested at $\lambda = 1.15$ μm. It is found that its crosstalk is less than -26 dB and switching voltage is 13 V. The bandwidth of the device has been measured to be greater than 1 GHz using a small-signal method. This switch is expected to be used in GaAs switching arrays.

I. Introduction

An optical switch is a basic component in any optical device. It is not only widely used in optical communications, optical computing and optical information processing, but also is a basic element in an optical switching array. Presently, there are the following

major types of waveguide 2 x 2 optical switches: conventional single-mode directional coupler (DC),[1] total internal refraction (TIR),[2] asymmetric X model,[3] asymmetric Mach-Zehnder interferometer,[4] and symmetric directional coupler BOA (bifurcated optically active).[5] In particular, the BOA has the largest mode dispersion ($\Delta\beta$), does not require a special fabrication length or range of length and can achieve a very low crosstalk ratio (below -40 dB in theory). Since this structure was introduced, a wide range of studies centering around $LiNbO_3$ have been conducted. At the present moment, the BOA switch typically has a crosstalk ratio of -28 dB, a half-wave voltage of less than 30 V-mm and a switching time of less than 1 ns.[6] However, due to manufacturing error, it is very difficult to lower the crosstalk ratio further. One of the primary sources of error is electrode alignment error. It is very difficult to eliminate electrode alignment error in manufacturing. GaAs is an active material that can be used in light sources, waveguides, detectors and integrated monolithic microelectronic devices. Furthermore, its operating wavelength can extend from near infrared to far infrared by way of bandgap engineering. Therefore, it is of considerable significance to develop a BOA optical switch using this material. This paper reports the development of a GaAs symmetric directional coupler BOA switch. In addition, an electrode self-alignment technique is employed in the fabrication of the GaAs waveguide to minimize electrode alignment error. This technique is expected to improve the yield and lower the crosstalk ratio of BOA switches.

II. Theoretical Analysis

A BOA optical switch is comprised of two single-mode waveguides and a straight two-mode waveguide (capable of transmitting the fundamental mode and first-order mode). As shown in Figure 1(a), when a beam of polarized light enters the input waveguide (either from 1 or 2), it excites two eigenmodes, a symmetric and an antisymmetric, in the bifurcated region. If the input waveguides are spaced by a multiple of the waveguide width, then the two eigenmodes are of equal amplitude. In the two-mode waveguide, the symmetric eigenmode becomes the fundamental mode and the antisymmetric eigenmode becomes the first-order mode. Figure 1(b) shows the optical field distribution in different regions. If adiabatic conditions are met and various mode losses are negligible, then the two modes propagate along the Y-axis at a constant amplitude ratio. Moreover, the symmetric and antisymmetric eigenmodes are orthogonal in all regions and cannot exchange any energy, i.e.,

$$\int \psi_s(x,y_1)\psi_a(x,y_1)dx = 0, \quad y_1 = y_1 + \Delta y \tag{1}$$

where ψ_s and ψ_a represent the symmetric and antisymmetric eigenmode field distribution, respectively.

In the two-mode waveguide, because the two eigenmodes propagate at different speeds, there is a propagation constant difference $\Delta\beta$. If the length of the two-mode waveguide is L, then the relative phase difference is $\Delta\varphi = \Delta\beta L$. The optical power output from terminal 3 or 4 can be expressed as follows:

$$P_3/P_{total} = 2(a_s a_a)\cos^2(\Delta\varphi/2) + (a_s - a_a)^2/2, \tag{2a}$$

$$P_4/P_{total} = 2(a_s a_a)\sin^2(\Delta\varphi/2) + (a_s - a_a)^2/2, \tag{2b}$$

where a_s and a_a represent the relative amplitude (ranging from 0 to 1) of the symmetric and antisymmetric eigenmode, respectively.

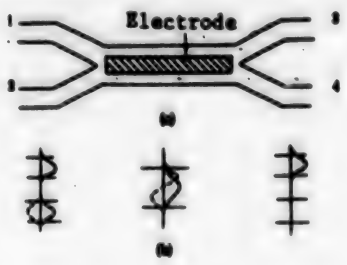

Figure 1. (a) Configuration of BOA and (b) Optical Field Distribution in Various Regions

If the index-of-refraction distribution is altered by means of optoelectronic perturbation, then the eigenmode propagation constant also changes. Therefore, the relative propagation phase difference, $\Delta\varphi$, in equation (2) includes two parts. One is the relative phase delay, $\Delta\varphi_e$, produced by optoelectronic perturbation and the other is the relative phase difference, $\Delta\varphi_0$, due to the difference in propagation speed of the two eigenmodes, i.e.,

$$\Delta\varphi = \Delta\varphi_e + \Delta\varphi_0.$$

If a switch is fabricated on the (100) plane of GaAs, then the relative phase delay is

$$\Delta\varphi_e = \pi/\lambda \cdot r_{41} L V \Gamma/d, \tag{3}$$

where Γ is the overlapping integral of the electric and optical field, L is the length of the electrode, V is the applied voltage, r_{41} is the optoelectronic coefficient of GaAs and d is the waveguide thickness. Based on the above analysis, only $\Delta\varphi$ is related to the optoelectronic effect in equation (2). Under the influence of the optoelectronic effect, if the relative phase difference is increased or decreased by a multiple of π, the light can be switched from one output end to the other to achieve a switching effect.

If a BOA switch is made of $LiNbO_3$, different electrode configurations can cause the fundamental mode of

first-order mode to vary. However, in a ridge waveguide BOA switch made of GaAs the electric field generated by the p-n junction or the Schottky barrier is perpendicular to the (100) plane. Furthermore, the electric field is distributed in the middle of the two-mode waveguide as shown in Figure 2(b). In addition, the fundamental-mode energy of the optical field is also distributed in this region. Hence, a GaAs BOA switch is primarily used to modulate the fundamental mode. Figure 2(a) shows the GaAs ridge waveguide configuration and electrode position. Figure 2(b) shows the electric field distribution (solid line) of a GaAs BOA switch and the energy distribution (dotted line) of the two eigenmodes.

If $\Delta\varphi_e = \pi$, then from equation (3) we have:

$$V_\pi = \lambda d / r_{41} L \Gamma \qquad (4)$$

From equation (4) we know that the half-wave voltage of GaAs is a function of the waveguide dimension and configuration. The half-wave voltage can be lowered by reducing the waveguide thickness or by increasing the electrode length. The overlap integral Γ can be raised by using a heterojunction structure and imposing strict constraints on the optical field to effectively lower the half-wave voltage. Furthermore, from Figure 2, one can see that electrode width also plays an important role in a BOA switch. If the electrode is too wide, it also modulates the first-order mode and the half-wave voltage will have to rise accordingly. When the electrode is too narrow, it affects the overlap integral Γ and lowers the modulation efficiency and raises the switching voltage. Hence, the optimal electrode width needs to be obtained by way of theoretical analysis and a great deal of experimental work.

Figure 2. (a) The Ridge Waveguide Structure and (b) the Electric Field (solid line) and Energy Distribution of the Two Eigenmodes (dotted line) in the Waveguide

III. Factors Affecting Crosstalk Ratio

Usually, crosstalk ratio is defined as follows:

$$10 \lg (P'_{out})_{min}/(P_{out})_{max} \cdot (dB)$$

where $(P_{out})_{max}$ is the maximum optical power output when the other output has the minimum output $(P'_{out})_{min}$.

Based on equation (2), the crosstalk ratio is a function of the ratio a_s/a_a. Deleterious factors causing a_s and a_a to be unequal include: (1) non-equimode excitation, (2) mode coupling due to asymmetry of the bifurcated region of the waveguide, and (3) difference in propagation loss of the two eigenmodes in any region due to factors such as scattering.[6] These deleterious factors will produce crosstalk. By way of design optimization and process improvement, the effect of such deleterious factors can be eliminated or reduced.

If there is sufficient separation of the input waveguide and output waveguide (e.g., by several widths of the waveguide), equimode excitation can then be obtained. In reference 6, the relation between a_s/a_a and the input single-mode waveguide was calculated using an effective refractance method. The results show that a 40 dB open-to-closed ratio could be obtained with a spacing of two waveguide widths. The asymmetry difference of the bifurcated single-mode waveguides is less than 0.02 μm when using a pattern generator or electron-beam mask making device and reduction in photolithography. This can effectively reduce the effect due to non-equimode excitation or mode coupling due to asymmetry of single-mode waveguides. Using a high-quality process and high-quality epitaxial material can reduce the transmission loss of different modes due to scattering. The use of a GaAs/GaAlAs heterojunction structure prepared by MOCVD or MBE as an epitaxial material can result in a perfect lattice and a shining surface. Furthermore, it effectively lowers transmission loss. In addition, electrode alignment error is another important factor affecting the crosstalk ratio. An asymmetric electrode pattern causes an asymmetric distribution of optoelectronic perturbation along the y-axis. In this case, as optoelectronic perturbation affects the fundamental mode, it also affects a part of the first-order mode to alter its symmetric distribution to create crosstalk. In reference 7, Lu Rongxin [7120 2837 9515] et al. calculated the effect of electrode alignment error on the crosstalk ratio. It was concluded that the electrode alignment error should be less than 0.5 μm in order to hold the crosstalk ratio to below -30 dB. In conventional techniques, electrodes are etched directly. Since the electrode is several millimeters long and only a few microns wide, precise alignment is very difficult. Especially in a switching array, it is even more difficult to align several switches. In order to minimize alignment error, a two-step etching process was developed based on the unique features of GaAs to achieve self-alignment of the electrodes. Figure 3 shows a portion of the switch fabrication process and the self-alignment technique.

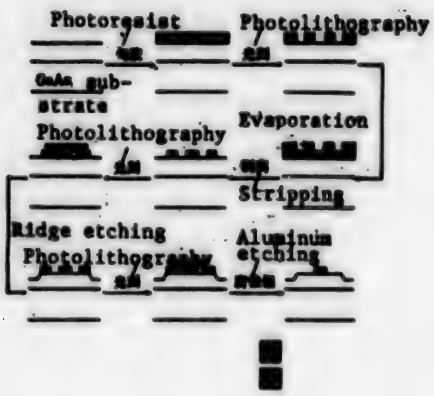

Figure 3. Self-Alignment of Electrodes

IV. Device Design and Fabrication

An effective refractance approximation method was used to design the device. The calculations show that the width of a GaAs n^-/n^+ ridge-type single-mode waveguide should be under 9 μm when the waveguide thickness is 2.5 μm and ridge height is 1.2 μm. On the basis of this result, we chose a single-mode waveguide width of 8 μm, ridge height of 1.2 μm and waveguide thickness of 2.5 μm. For ease of fabrication, the bifurcated region is an oblique waveguide with a 1° angle. The two-mode waveguide is 16 μm wide, the active region is 8 μm wide and 6 mm long.

The device was fabricated on an n^- layer ($n^- \leq 10^{15}$ cm^{-3}) prepared by vapor phase epitaxy over a heavily-doped ($n^+ \geq 10^{18}$ cm^{-3}) GaAs substrate. The epitaxial layer must have a sufficiently low impurity level, a perfect lattice, a relatively steep transition layer and a shining surface to minimize waveguide loss and scattering. The electrodes were made by using a stripping and self-aligning technique. A wet etching method was employed to make the ridge and the etchant used is $H_3PO_4 : H_2O_2 : H_2O = 1:1:10$. It was etched for 2 minutes at 25°C. The upper electrodes are Al-Schottky electrodes and the lower electrodes are Au-Ge-Ni ohmic contacts.

V. Measurements and Results

A 1.15-μm-wavelength He-Ne laser was used as the light source. The beam was focused before entering the waveguide. The modulated beam exited the waveguide from the other end. It was then collimated by another lens and an infrared camera was used to capture the output light spot. It was stored in a waveform storage device and displayed on an oscilloscope. Figure 4 is a diagram of the test apparatus. Figure 5 (see photograph plate I [not reproduced]) shows the light spots and optical-field distributions corresponding to dc voltages of 10, 15 and 20 V. The crosstalk ratio of the device at a 20 V bias is less than -26 dB. Figure 6 shows the curve for output energy versus voltage. The switching voltage is 13 V and the crosstalk ratio is -22.4 dB. The frequency response of the switch was measured using a small-signal method. It was found that the 3-dB bandwidth is greater than 1 GHz, as shown in Figure 7.

VI. Conclusions

A 2 x 2 GaAs BOA optical switch has been developed. An electrode self-alignment technique was employed to achieve a crosstalk ratio of -26 dB and a switching voltage of 13 V. The 3-dB bandwidth is greater than 1 GHz. This self-alignment technique, when used in the fabrication of BOA switching array, can make the array more stable and reproducible. It can also improve the yield. The BOA optical switch is an important switch element in a GaAs switching array.

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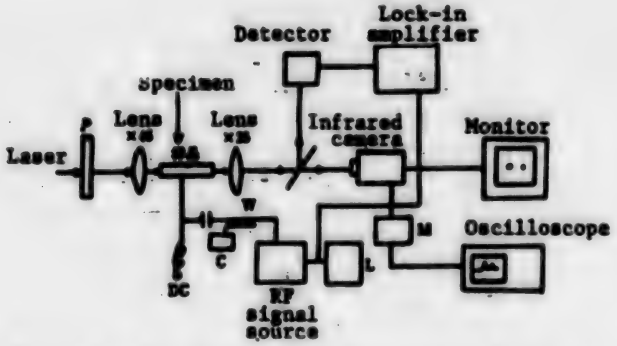

Figure 4. Principle of the Measurement System

L -- low-frequency generator; M -- memory; C -- crystal detector; W -- microwave coupler; P -- polarizer

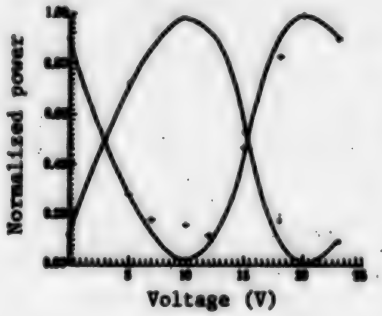

Figure 6. Output Energy vs. Bias Voltage

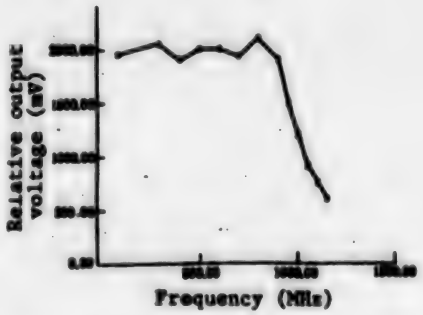

Figure 7. Frequency Response Characteristics of the Switch

Analysis of Range-Alignment in ISAR Imaging

93FE0803A Beijing DIANZI KEXUE XUEKAN [JOURNAL OF ELECTRONICS] in Chinese Vol 15 No 3, May 93 pp 300-304

[Article by Pi Yiming [4122 0076 7686] and Huang Shunji [7806 7311 0679] of the University of Electronic Science and Technology, Chengdu 610054; MS received 18 Nov 91, revised 21 Sep 92]

[Text] **Abstract**

In this paper, the basic theory of range-alignment in inverse synthetic aperture radar (ISAR) imaging is presented. Two new methods of range-alignment are proposed: the peak-value alignment method and the direct alignment method. The differences between these two methods are illustrated using measured radar data; the results clearly show the advantages of the direct alignment method.

1. Introduction

In recent years, scientists around the world have devoted much attention to inverse synthetic aperture radar (ISAR), which has emerged as one of the most promising approaches for solving problems of counter-stealth and target recognition.

A key issue in ISAR imaging is motion compensation, which is generally accomplished in two steps: the first step is range-alignment, which eliminates any range drift in the target returns; the second step is phase compensation, which corrects the phase of the target returns. Currently, most imaging techniques use spatial alignment or amplitude alignment for range correction.[1-5] A representative method is the amplitude correlation method proposed by Chen;[1] however, this method has the disadvantage that when the correlation of the target return is poor, large error may be present in the drift estimation. In this paper, two new methods of range-alignment are proposed: the peak-value alignment method and the direct alignment method. The advantages and disadvantages of these three methods are analyzed using field-measured radar data. The results show that the direct alignment method is superior to the others; also, its application can be extended to provide images of satellite targets.

2. Range-Alignment

In order to obtain high-resolution two-dimensional images in ISAR, it is necessary to reduce the widths of the range cells and to increase the coherent integration time. However, under these conditions, the range drift in the pulse returns may be increased because of target scintillation effects. During the period of coherent processing, large variations in range may exist from pulse to pulse, and the envelope function of the returns may be several times greater than the transmitted pulse width. Therefore, prior to image processing, range-alignment should first be applied to the samples of the return signals in order to eliminate range drift. To address this problem, Chen[1] first proposed the amplitude correlation method. Let $x_1(r)$ and $x_2(r)$ be the complex envelopes of two adjacent return pulses, where r is the range. Since radar returns are signals of finite energy, $x_1(r)$ and $x_2(r)$ can be regarded as two elements of the Hilbert space. Within one pulse repetition period, the attitude variation of a fast-moving target is quite small, hence the return signal varies sufficiently slowly to be represented by its amplitude function, i.e.,

$$m_1(r + \Delta r) \approx m_2(r) \qquad (1)$$

where $m_1(r)$ = magnitude of $x_1(r)$, $m_2(r)$ = magnitude of $x_2(r)$. Δr denotes the misalignment in the return data, i.e., the value of range drift to be estimated.

In theory, range alignment implies minimizing the distance between $x_1(r)$ and $x_2(r)$, or the distance between the actual signals $m_1(r)$ and $m_2(r)$.

The distance between $m_1(r)$ and $m_2(r)$ in Hilbert space can be expressed as:

$$d^2(m_1, m_2) = \|m_1 - m_2\|^2 = \|m_1\|^2 + \|m_2\|^2 - 2(m_1, m_2) \qquad (2)$$

Since the signal energy is unchanged by a time shift, it follows from equation (1) that

$$\|m_1\|^2 = \|m_2\|^2 \qquad (3)$$

Thus, the range can be expressed as:

$$d^2(m_1, m_2) = 2[\|m_1\|^2 - (m_1, m_2)] = 2[R(0) - R(s)] \qquad (4)$$

where

$$R(s) = \int_{-\infty}^{+\infty} m_1(r) m_2(r - s)\, dr \qquad (5)$$

R(s) is the correlation function between the two signals $m_1(r)$ and $m_2(r)$. Based on the Schwartz inequality and equation (1), it is clear that the value of R(s) reaches a maximum when $s = \Delta r$, which corresponds to minimum distance between $m_1(r)$ and $m_2(r)$.

The above procedure for computing the misalignment Δr is the basis of the amplitude correlation method. Clearly, the success of this method requires that returns from adjacent pulses have good correlation. However, in cases where noise is present in the target

returns, or where large range drift exists and the coherent integration time is long, amplitude correlation between the returns may be destroyed, resulting in large estimation error.

To address the above problem, we have proposed two improved methods of range alignment.

Method 1 (Peak-Value Alignment Method): Assume that the target has a strong point-scatterer in a particular range cell so that the return samples from this range cell are dominated by the point-scatterer. Therefore, by locking the strongest returns from different pulses in the same range gate, phase compensation can be applied to the return samples to produce highly focused images. However, when the return pulses do not have clearly defined peaks, the peak-value alignment method may produce large estimation errors.

Method 2 (Direct Alignment Method): In Hilbert space, the distance between two signals $m_1(r)$ and $m_2(r)$ is generally defined as:

$$d^2(m_1, m_2) = \int_{-\infty}^{\infty} [m_1(r) - m_2(r)]^2 dr \quad (6)$$

In order for R(s) to be a maximum, the distance given by equation (6) must be a minimum. By interpreting this distance to be the mean square amplitude error

$$\sigma_1^2 = \int_{-\infty}^{\infty} [m_1(r) - m_2(r)]^2 dr \quad (7)$$

then the range misalignment can be determined by finding the value of Δr that minimizes σ_1^2.

3. Analysis

The purpose of motion compensation in ISAR imaging is to remove the phase variation caused by the relative motion between the radar and target. It can be shown[6] that if a range cell contains a strong point-scatterer whose return strength is at least 4 dB higher than the sum of the returns from all other scatterers in the same range cell, then it can be used as the phase reference for motion compensation.

Let $m_n(k)$ be the return amplitude of a target in the kth range cell in response to the nth radar pulse; one can calculate the mean value and the mean square value of $m_n(k)$ as follows:

$$\overline{m(k)} = \frac{1}{N} \sum_{n=1}^{N} m_n(k)$$

$$\overline{m^2(k)} = \frac{1}{N} \sum_{n=1}^{N} m_n^2(k) \quad (8)$$

The normalized mean square error of the range cell is defined as:

$$\sigma_2^2 = (\overline{m^2(k)} - \overline{m(k)}^2)/\overline{m^2(k)} \quad (9)$$

The range cell with the smallest value of σ_2^2 will have the smallest amplitude fluctuation and the most stable phase; therefore it can best serve as the phase reference.

In this paper, we have used the mean square amplitude error between adjacent pulses, σ_1^2, and the normalized square error of the reference cell, σ_2^2, as the criteria for measuring the performance of the three range-alignment methods. The magnitude of σ_1^2 reflects the degree of success of range-alignment, and the magnitude of σ_2^2 is directly related to the effectiveness of motion compensation.

We have conducted an experiment where FM-CW radar was used to create images of an aircraft model; a total of six independent pictures have been obtained. The aircraft model used in the experiment is a model of the F-7 aircraft used in wind-tunnel testing; its surface is covered with a sheet of aluminum, as shown in Figure 1. The experiment was conducted in an open field, and a steerable radar was used to simulate realistic field conditions.

Figure 1. Aircraft Model With a Length of 3.1 m and a Wing Span of 1.64 m

Table 1 summarizes the values of σ_1^2 and σ_2^2 obtained by applying different range-alignment methods to the raw data collected by the millimeter-wave radar during the experiment.

Table 1. Square Errors of the Three Range-Alignment Methods

Square error	First segment				Fifth segment			
Method of alignment	σ_1^2 between 7th and 8th pulses	σ_1^2 between 27th and 28th pulses	σ_2^2	Total drift number	σ_1^2 between 7th and 8th pulses	σ_1^2 between 27th and 28th pulses	σ_2^2	Total drift number
Amplitude correlation	0.983	1.580	0.120	3	1.638	1.094	0.104	6
Peak-value alignment	1.081	1.792	0.146	5	1.676	1.094	0.087	4
Direct alignment	0.983	1.569	0.117	2	1.625	1.094	0.098	5

By comparing the square errors and the total drift number between the three methods, the following conclusions can be drawn. The amplitude correlation method basically reflects the statistical average of the range amplitudes; it is relatively insensitive to noise, and produces good results in the first segment where the amplitude peaks are not clearly defined; it also gives an accurate estimate of the range drift number. The peak-value alignment method yields good results in the fifth segment, which contains a strong point-scatterer; it also yields the smallest normalized square error σ_2^2 in the reference range cell, but the amplitude square error between adjacent pulses and the error in the estimate of drift number are quite large, particularly when the return amplitude peaks are not clearly defined. The direct alignment method performs well in both the fifth data segment and the first data segment; it not only provides optimum results in terms of σ_1^2 and σ_2^2, but also gives accurate estimates of the drift number. It is known from reference 1 that serious adverse effects will result if the range-drift error exceeds one range cell; the direct alignment method is relatively insensitive to this error.

Figure 2. Images of the First Data Segment
(a) Direct alignment method;
(b) Amplitude correlation method

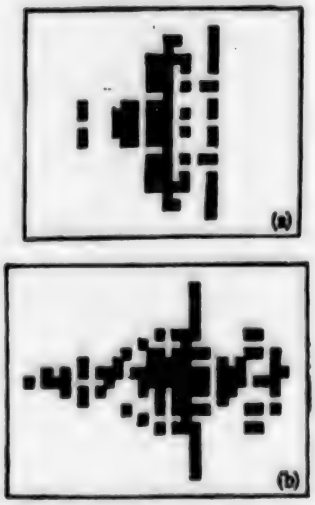

Figure 3. Images of the Fifth Data Segment
(a) Direct alignment method;
(b) Amplitude correlation method

By first applying range alignment and motion compensation to the measured data, we have obtained four images which corresponds to the first segment and the fifth segment, as shown in Figure 2 and Figure 3. Each data segment contains 32 pulse samples; image (a) corresponds to the result of range alignment using the direct alignment method and image (b) corresponds to the amplitude correlation method. All four images have been produced using azimuth weighting, threshold processing and axially symmetric inversion.

It can be seen from Figure 2 and Figure 3 that the strong point-scatterers are concentrated in the tail section, whereas the scattering strength of the nose section is rather weak; in other words, the dynamic range of the scattering characteristics of the aircraft is quite large. The direct alignment method not only mitigates the effect of the strong scatterers, it also preserves the weak but important image elements of the nose section. On the other hand, the amplitude correlation method may cause fuzziness in the images and may also drop the weaker elements of the nose section. In summary, the effectiveness of the direct alignment method has been clearly demonstrated by the clarity and good resolution of the aircraft images.

4. Concluding Remarks

The advantages of the direct alignment method can be summarized as follows:

(1) The direct alignment method can be effectively applied to target returns with strong point-scatterers as well as returns with slowly varying distributed scatterers; it has exhibited good adaptability and stability for a wide range of different target types.

(2) The computation load for the direct alignment method is smaller. For instance, in a 64-point imaging area, the amplitude correlation method requires 2,560 multiplications (including three Fourier transforms), but the direct alignment method only requires 2,048 multiplications.

(3) The amplitude correlation method can only correct the effect of range drift whereas the direct alignment method can also correct for range bending.

(4) The direct alignment method is particularly suited for ISAR imaging of satellite targets where large range drift and high noise level are present and where long coherent integration time is required.

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HTS Josephson-Junction 90 GHz Harmonic Mixing

93FE0758A Beijing KEXUE TONGBAO [CHINESE SCIENCE BULLETIN] in Chinese Vol 38 No 8, 16-30 Apr 93 pp 687-689

[Article by Wang Huabing [3769 5478 0365], Xu Weiwei [6079 0251 0251], Cheng Qiheng [4453 0366 1854], and Wu Peiheng [0702 1014 0077] of the Department of Information Physics, Nanjing University and Zhang Shiyuan [1728 0013 6678] and Zhang Hongcai [1728 7703 2088] of the Department of Physics, Nanjing University: "High-Temperature-Superconductor Josephson-Junction 90 GHz Harmonic Mixing"; MS received 31 Aug 92, revised 18 Dec 92, supported by the National Superconductor Technology Development Center and Higher Learning Institution Doctoral Research Fund]

[Text] **Abstract**

Compared to other semiconductor devices, the Josephson junction has a variety of unique characteristics including high degree of nonlinearity, low noise, wide operating band and low power consumption. The Josephson junction has been used in many studies in the millimeter, sub-millimeter, and far-infrared bands.[1-6] Blaney et al. used a Nb-point-contact junction to conduct a harmonic mixing experiment and the highest frequency reached was 4.25 THz[6] and the largest harmonic was 851.[4] That study could be applied in metrology or frequency locking. However, because it was done at liquid-helium temperature (4.2 K), it has a limited range of applications.

Since the advent of high-T_c superconductors (HTSs), which operate at liquid-nitrogen temperature (78 K), the prospect of future applications has broadened. In 1988, Song et al. used HTSs to observe the mixing of four harmonics on the Ka band.[7] Later, Wu et al. measured the mixing of 51 harmonics at 76 GHz.[8] This paper presents the results of harmonic mixing involving as many as 67 harmonics at 90 GHz. In addition, the relation between the intermediate-frequency (IF) output of a harmonic mixer with its local oscillation (LO) power and dc bias is also studied. The results are compared to those obtained from a simulated Josephson-junction circuit.

1. Selection of Josephson Junction

The method to prepare the Josephson junction used in this experiment was reported in reference 9. By measuring the ac and dc I-V characteristic curves, it is possible to choose the HTS Josephson junctions that suit the requirements for harmonic mixing. The selection criteria are as follows:

1.1 Critical Junction Current I_c

The sensitivity of Josephson-junction harmonic mixing is generally inversely proportional to I_c. Nevertheless, it is usually easier for a junction with a higher I_c to reach a higher number of microwave induction plateau to consequently achieve a higher-order harmonic mixing. We believe that the selection of a suitable I_c is imperative. After conducting a large number of experiments, it was found that I_c should be between 100 and 1,000 μA.

1.2 Junction Resistance R

The resistance of a HTS Josephson junction is usually very low, of the order of ohms. The impedance of the microwave circuit, on the other hand, is several hundred ohms. Therefore, junctions with high resistance should be selected in order to match them properly. In the experiment, several steps were taken in the junction fabrication process to raise the normal junction resistance.

1.3 I_cR

In theory, it is usually believed that the product of I_c and R represents the characteristic frequency of the junction, f_c, i.e., $f_c = (2e/h)I_cR$. However, in this HTS mixer experiment we discovered that I_cR could not completely represent the characteristic frequency of the junction. In many cases, IF output could still be obtained even when the signal frequency was higher than f_c. One possible cause is that the YBCO junction is a grain boundary structure. Presently, the values of I_cR for junctions prepared range from 50 μV to 500 μV. A junction with a higher I_cR value often has a higher-order microwave induction plateau and a larger IF output. Hence, one is better off to choose a junction with a large I_cR value. It was experimentally found that I_cR is primarily determined by material characteristics.

1.4 Requirements on ac and dc I-V Curves

We believe that the upper critical current I_c of the junction should take a sharp turn in the I-V curve. Upon illumination by LO power, it should have apparent microwave induction plateaus exceeding the number of harmonics. Furthermore, the larger the number of induction plateaus is, the better the junction behaves. With respect to the signal power, one only needs more than one apparent induction plateau to meet the requirements of higher-order harmonic mixing.

Figure 1 [photograph not reproduced] shows the ac and dc I-V curves of a junction used in this work. From Figure 1(a) one can see that the critical current I_c of the I-V curve of the junction makes a sharp turn, instead of a smooth arc, with I_c = 150 μA, R = 3.0 sL, I_cR = 450 μV. Figure 1(b) is the ac I-V curve of the junction upon irradiation by 8-mm microwaves. One can see that there is an apparent microwave induction plateau at 4 mV indicating that the junction is still in Josephson oscillation at 4 mV (1.9 THz). This suggests that the maximum operating frequency of this junction may reach as high as the sub-millimeter or far-infrared band. Figure 1(c) shows the ac I-V curve of the junction upon irradiation by 3-mm microwaves. There are apparent microwave induction plateaus in the figure.

Since the junction is a grain boundary junction containing numerous YBCO particles to form a serially and parallelly connected structure, the microwave induction plateau in the figure shows up at the position of the fourth induction plateau. In conclusion, this junction meets the requirements for harmonic mixing.

2. Experiment Apparatus and Results

The experimental apparatus for harmonic mixing is the same as that described in reference 8. In the setup, the LO signal source is a standard signal generator with a maximum output power of more than 10 mW. The frequency is measured with a digital frequency meter. The LO signal is illuminating on the junction through a coaxial cable. The signal source is a solid state oscillator with an output of approximately 10 mW. It irradiates the junction through a waveguide. The IF amplifier is a low-noise amplifier with a noise temperature < 100 K; its operating frequency is 40 to 150 MHz and it has a gain of approximately 46 dB. The spectral analyzer is an HP8590B.

Using the apparatus described above, the mixing of different orders of harmonics of the 90 GHz signal was studied over an LO range of 1.3 GHz to 10 GHz. The highest-order harmonic is 67. Figure 2 [photograph not reproduced] shows the output signal of the mixing of 67 harmonics. Its LO frequency is 1.333450 GHz and the IF frequency is 117.79 MHz. Hence, the measured signal frequency is 89.45894 GHz.

In the harmonic mixing of a low-T_c superconductor, the IF output of the junction depends on factors such as voltage bias and LO. To this end, harmonic mixing experiments were conducted on HTSs. Comparing Figure 2 to Figure 3 [photograph not reproduced], with a fixed bias, there is an optimal LO power associated with each HTS harmonic mixing. In this case, the IF signal output is the highest. This is because the IF output of the mixer is proportional to the differential resistance, R_d, at the point of the junction and the differential resistance of a Josephson junction is a function of the external LO power (Figure 3). This is consistent with the results of electronic simulation. (Footnote 1) (Fan Minhua [5400 2404 5478], Huang Yinghong [7806 1758 5725], and Cheng Qiheng, DIWEN WULI XUEBAO [CHINESE JOURNAL OF LOW TEMPERATURE PHYSICS] (to be published).)

Figure 4 shows the relation between the IF signal output and the dc bias current in the mixing of 67 harmonics. The figure shows that the mixer has a certain IF signal output when the bias current I_b increases from 0 to 700 μA. However, when I_b is large (> 0.8 mA), the IF signal disappears. This indicates that the IF signal power does not depend on the bias current I_b by much over a certain range. It is worthwhile noting that there is an IF output of the mixing of 67 harmonics even when $I_b = 0$. This is inconsistent with the circuit simulation result.[1] Additional study is required.

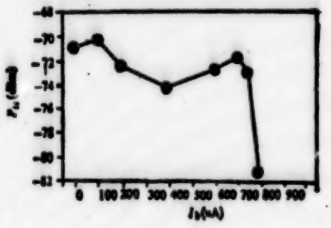

Figure 4. IF Output Voltage vs. dc Bias During Mixing of 67 Harmonics

3. Conclusions

By choosing the appropriate junction, we successfully realized mixing of 67 harmonics at 90 GHz in an HTS Josephson junction. The signal-to-noise ratio is better than 10 dB. This is an HTS junction frequency mixing experiment that involves the largest number of harmonics and at the highest operating frequency. The results indicate that the IF output of harmonic mixing is a function of the LO; however, it does not appear to be related to the dc bias current I_b. HTS junctions have the potential to work at even higher frequencies and have a bright future in practical applications.

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U.S. Digital HDTV Group Demonstrates Technology in Beijing

93P60307A Beijing ZHONGGUO DIANZI BAO [CHINA ELECTRONICS NEWS] in Chinese 28 Jun 93 p 1

[Article by Liu Dong [0491 2639] and Wei Wei [7279 0251]: "Digital High-Definition Television Demonstration Held in Beijing"]

[Summary] A U.S. high-level TV research group—in cooperation with GE and RCA license companies, the Ministry of Electronics Industry (MEI) Communications and Broadcast TV R&D Center, and the Ministry of Radio, Film and Television (MRFT) Broadcasting Sciences Institute—held a high-level digital HDTV demonstration and exchange in Beijing on 22-24 June. MEI Minister Hu Qili and Vice Minister Lu Xinkui, among other officials, attended the opening ceremony. It was also learned at the demonstration that the "Flying Rainbow" Plan—jointly formulated by the Former MMEI, MRFT, and the State Physical Education Commission and aimed at developing a series of HDTV equipment for the Beijing 2000 Olympic Games [see JPRS-CST-93-002, 27 Jan 93 p 44]—is now being implemented.

Domestic Network of 19 Satellite Earth Stations Under Construction

93P60307B Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 25, 30 Jun 93 p 1

[Article by Jiang You [3068 1429]: "Nation To Build Complete Domestic Satellite Communications Network"]

[Summary] China is now building anew or expanding a total of 19 satellite earth stations forming a domestic network stretching east to Shanghai, west to Urumqi, south to Haikou, and north to Harbin. The network, centered on Beijing, covers the entire territory of China and will be completed and in operation in 1994. The network uses TDM (time-division multiplexing), TDMA (time-division multiple access), and IDR (intermediate data rate) technologies and formats, and incorporates such advanced technologies as code compression and digital speech interpolation. One 2 Mbit-bandwidth digital channel (ordinarily capable of transmitting 30 voice circuits) can transmit 120 simultaneous voice circuits via these new technologies. After completion of this network, all 19 stations will be up-linked to the DFH-3 new-generation communications satellite, whose transponders will relay the digital signals down to all domestic points.

Domestic Public Network ISDN Research Advances Highlighted

93P60307C Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 27, 14 Jul 93 pp 131, 133

[Article by Zhao Huiling [6392 1979 3781] of MPT's Telecommunications Transmission Institute: "Nation's Public Network ISDN Research Advances"]

[Summary] In March 1991 (Seventh FYP), the nation's first ISDN model network, developed by MPT's Telecommunications Transmission Institute, was completed. This model network permitted the following basic functions: providing terminal-to-terminal digital connections, providing digital subscriber signaling functions (i.e., D-channel physical layer, data link layer, and network layer functions), and providing interconnections between ISDN model network and existing telephone networks and packet-switching networks. This model permitted 64 kbit/s unrestricted circuit-switched bearer services according to the X.31 protocol, mode A. Equipment included two ISDN-capable switches, one packet switch (X.25 protocol), nine identical network termination 1 (NT1) units, six terminal adapters, and nine varieties of terminals. The two ISDN switches were connected by fiber optic cable, a packet switch, and an access unit(s). The model network was tested with CCITT's digital subscriber signal #1 (DSS1) recommendation.

In the current (Eighth) FYP, an ISDN experimental network is being developed. Eighth FYP targets are as follows: further improve all functions of the ISDN network, strive to enter a utilitarian phase, and perfect all test segments of the network.

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16 SEPT 1993